FISCAL YEAR 1990 DEPARTMENT OF ENERGY AUTHORIZATION

(Basic Energy Science and General Science and Research)

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

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1990 DEPARTMENT OF ENERGY AUTHORIZATION

THURSDAY, FEBRUARY 23, 1989

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Energy Research and Development,
Washington, DC.

The Subcommittee met at 9 a.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd (Chairperson of the Subcommittee) presiding.

Present: Representatives Lloyd, Morrison, Fawell, Schiff, Henry, Smith and Walker.

OPENING STATEMENT OF HON. MARILYN LLOYD, CHAIRMAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mrs. Lloyd [presiding]. The Subcommittee will come to order.

Good morning, ladies and gentlemen.

We do have a full plate of items that we must address, since we are combining two programs into—two major programs into one hearing this morning.

I know that we have a lot of witnesses, very important, very knowledgeable witnesses, with us today, and I also know that we really need to complete our hearings by noon today.

Therefore, I will ask all of our witnesses to adhere to the time limit that we announced in our letter of invitation, and I do apologize, for the pressures of the budget process in a new Congress are really putting severe time constraints on the committee's deliberations this year. However, we will be holding oversight hearings later on in the year, and this won't be your last chance at this committee to give us your views. Certainly, they are very important to us.

Some of the key issues that I hope we can address today include the role of the superconducting super collider in the Department's budget proposals for fiscal year 1990 and its impact on other scientific endeavors that this committee has supported over the years.

I know the Department has stated that the SSC would not impact funding for other important science enterprises, but in the strained fiscal situation that we find ourselves now, with a need to reduce budget deficits, it is certainly hard for me to believe that even the best intentions of the Department can prevent the very serious impacts on the science programs from a project as large as SSC.

For example, an important facility, the advanced neutron source, has not been provided their required funding level in the Department's fiscal year 1990 budget. Also, this committee strongly urged the Department to initiate construction activities for RHIC, and again this proposed Administration's fiscal year 1990 budget does not include the construction funds for this project.

So in spite of these concerns and other concerns that I can mention, particularly in the area of university research support programs, I am pleased that the Department has chosen to increase budgets in the basic energy science programs by an average of about 10 percent over last year's appropriations.

It also appears that the Department is placing greater emphasis on higher temperature superconductivity research, which could lead to new and exciting technological advances.

I do look forward to hearing from our witnesses that represent the National Laboratories. I am certainly pleased that an old friend of mine, Dr. Al Trivelpiece, who is now the Director of the Oak Ridge National Laboratory and is now a constituent of mine, is here with us today.

At this time I would like to introduce my colleague and good friend, Congressman Sid Morrison.

OPENING STATEMENT OF HON. SID MORRISON, RANKING REPUBLICAN, SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Mr. MORRISON. Madam Chairman, you will do anything to get a constituent of the quality of Al Trivelpiece, won't you?

Mrs. LLOYD. Maybe we work at it.

Mr. MORRISON. I look forward to this session. We are on sort of a marathon pace, and we trust that we won't miss a lot of detail in the process, but I am delighted to see the number of people who are in attendance today.

We are proud of a lot of things that you do, and I would like to enter in the record, Madam Chairman, a long list of things that are a part of these programs that we believe are ideal, and we would like to do more.

I believe innovative research in basic energy and general sciences is important, and I also think that university research is one area in which a small investment can yield a significant return. We must not overlook these R&D programs because their technology spinoffs can lead to the enhancement of our quality of life, and that has been demonstrated in the past.

One parochial interest, Madam Chairman. Delighted to see that the Administration has included in the budget request a new initiative to establish the Molecular Science Research Center at the Pacific Northwest Laboratories, an international user facility that can provide leading edge equipment for a diverse group of researchers in various disciplines in the national laboratories, universities, and industries, and Dr. Bill Wiley, one of my favorite constituents, is here to talk about that.

Madam Chairman, I look forward to the hearing.

Mrs. LLOYD. Thank you very much.

Without objection, your entire statement will be made a part of the record.

One of my classmates is here. Since we are all getting a little folksy this morning.

I came to Congress in January of '75 with Norm Mineta. I think we are called Watergate babies, is that right, Norm?

Mr. MINETA. Or the revolting group, one of the two. [Laughter.]

Mrs. LLOYD. But we have managed to stay. We were just reelected, right, Norm, and certainly he is a good friend of mine and one of the outstanding Members in the United States Congress.

We would like to recognize you at this time, Norm.

Mr. MINETA. Thank you very much, Madam Chairwoman, Congressman Morrison, and members of the subcommittee. It really does give me a great deal of pleasure to have this opportunity to join my fine new colleague from the 12th Congressional District in Campbell, Tom Campbell, to have this opportunity to introduce two noted scientists who will present testimony to you this morning.

First of all, Dr. Burton Richter, Director of the Stanford Linear Accelerator Center, joined the center during its construction in 1963, and he did such a good job at that that he was honored with a share of the Nobel Prize in physics in 1976 for his contributions at SLAC, where he has been Director since 1984.

To this day, the 2-mile long linear accelerator constructed at the center in 1966 still generates the highest energy high intensity electron beams in the world. The accelerator continues to make major contributions to our understanding of nature.

The center also continues to challenge the frontiers of science by proposing a new linear collider in which the beams of two linear accelerators collide directly. SLAC has taken the first step in this research area by producing collisions using beams from the existing line.

The excitement of this new kind of machine and the new physics research areas available to it has captured the enthusiasm and participation of the international physics community.

The second individual it is my honor and pleasure to introduce today is Dr. David Shirley, Director of the Lawrence Berkeley Laboratory. During his 9-year tenure as its Director, the Lawrence Berkeley Laboratory, LBL, has initiated several new scientific programs, including the advanced light source, the Human Genome Center, and the Center for Advanced Materials.

These innovative research areas will provide important leadership for scientific programs throughout the Nation, and I am sure that Dr. Shirley will present his opinions about what is needed to ensure the success of Department of Energy programs.

Since he has announced that he will return to the bench in June as a full-time researcher, this is probably Dr. Shirley's last testimony before this subcommittee as Director of LBL. He will then leave an excellent testimony to his tenure as Director, and that is a rebuilt and revitalized LBL ready for the research of the 1990s.

The Science, Space, and Technology Committee, this subcommittee, and our nation at large owes Dr. Shirley our gratitude for his efforts on behalf of our national research endeavors, and I want to personally thank him for continuing to make me proud that I am a U.C. Berkeley alumnus. [Laughter.]

Thank you very, very much.

Mrs. **Lloyd**. Thank you very much, Norm.

Mr. **Mineta**. I would like to yield, if you would not mind my taking that prerogative, to my fine new colleague from California and a member of our Science, Space, and Technology Committee, Mr. Campbell.

Mrs. **Lloyd**. The Chair recognizes the Honorable Tom Campbell.

Mr. **Campbell**. Thank you, Madam Chairman. Thank you, my colleague Norm Mineta, and it is a real honor. Thank you for accommodating me.

To represent the Bay Area with Norm Mineta is quite an experience. The man represents all the Bay Area with distinction, and he has been nothing but kind to me in coming to Congress.

I am here for a very important reason, and that is to recognize and bring to the attention of the committee the fact that I have a Stanford faculty colleague testifying this morning, Dr. Burton Richter. So we can put an end to this discussion of U.C. Berkeley right now. [Laughter.]

I do want to just mention the following, if I may.

The Stanford Linear Accelerator Center has been a jewel on the Stanford campus, where I was until January 3rd a professor and thus a colleague of Dr. Richter. It will be very, very soon actually putting into full operation the Stanford linear collider, the last of three rings at the end of long linear accelerator, and the construction of that has been a model of good neighborliness. I know because we live right next-door to it.

Finally, let me add that the importance of the testimony that a person of Dr. Richter's caliber brings is obvious. I can do very little to add to that, and so I will simply say that my presence here today, gratefully allowed by Madam Chairman and my colleague Norm Mineta, is a testimony to the importance that all of us in the Stanford community and in the Bay Area attach to the fine work of Dr. Burton Richter and his qualities over the last 33 years as a member of the faculty of Stanford University.

Mrs. **Lloyd**. Thank you so much. Thank you for being with us, and we are delighted that you are with us as well.

Our first witness today is the Honorable Joe Barton, who served us well as a member of this committee, and, Joe, we look forward to your testimony at this time, as well as the testimony of Jim Chapman, who just recently left us, who was certainly an outstanding member of this committee. We miss you.

Please proceed.

STATEMENT OF HON. JOE BARTON, REPRESENTATIVE IN CONGRESS OF THE UNITED STATES FROM THE SIXTH DISTRICT OF TEXAS

Mr. **Barton**. Thank you, Madam Chairman.

I might say that Texans have a history of being pretty smooth operators, but I don't think we have got anything on California, watching Mr. Mineta and Mr. Campbell operate.

Mrs. **Lloyd**. That is a pretty hard act to follow.

Mr. **Barton**. Pretty good team. Pretty good team.

It is a delight to be here before my old subcommittee. It is good to see you and my friends, Congressmen Morrison and Fawell and Henry and Congressman Smith.

I am here today to testify on behalf of the superconducting super collider high energy particle accelerator.

As you know, this machine was originally competitively bid in over 25 States. The Secretary of Energy last year chose the State of Texas, and not only my State but my county and my hometown. The super collider ring is literally in my backyard.

I am here today to encourage you and the other subcommittee members to authorize funding for this vital research project because it will be one of the most important research projects that the United States has ever undertaken. It will be the world's most powerful proton-proton collider, producing particle collisions with total energies approaching 40 trillion electron volts.

Since the emergence of high energy physics as a separate field of research, the United States has led the world. However, I am concerned about losing our preeminence in high energy physics, first to Europe with the Center for European Research-Nuclear, which we call CERN, and perhaps to the Soviet Union with their planned collider that they call the UNK.

And I guess you would pronounce that "UNK." I am not a Russian, but that is how I would pronounce it.

By building the SSC, the United States will maintain our leading position in high energy physics research.

Since 1975, American scientists have won half of all Nobel Prizes in physics. However, the Europeans have won the last eight. This is a clear indication that we are losing our leadership position in high energy physics, and as you know, if we ultimately lose our leadership position in high energy physics, we will then lose our leading position in world economics.

If the SSC is not constructed in the United States, future U.S. generations will be forced to buy the technologies of tomorrow from the nations that are willing to invest in the SSC today. An investment in the SSC is really an investment in the future.

I have seen estimates that if we build the SSC in the United States we will generate new markets that approach $10 billion by the year 2000.

Now, some of the opponents of the SSC claim that the SSC will adversely affect our research and development projects in other basic science. In my opinion, just the reverse is true. Areas such as superconductivity, photonics, robotics, and supercomputing will receive increased emphasis because we build the SSC. The SSC is the bellwether project for investment in areas of basic research in the hard science area and will provide a major boost to the U.S. economy.

As you also know, the President has advocated doubling the National Science Foundation budget by 1990 or 1991. I support this increase. The United States must commit the resources to assure initiatives for the continued economic health of future generations.

The SSC is not part of this doubling of the NSF budget, but it is a compliment to that effort. Together, those two initiatives, or these two initiatives, will keep the United States number one in basic research in the world.

The expected cost of the SSC is $5.9 billion. That is not a 1-year cost. That is a 10- to 12-year cost, depending on how long it takes to construct the project. Of this $5.9 billion, approximately $4 billion is expected to be raised through the general revenues of the U.S. Treasury.

That means that approximately $2 billion is going to come from nonfederal sources. The State of Texas and its voters have committed $1 billion in cost sharing. Many of our European allies and our Asian allies have indicated that if the United States will make a commitment, a construction commitment to the SSC, they are very interested in helping us cost share on this project.

The budget request for this year for the SSC is $250 million. Let's put that in perspective.

We are expected to spend at the Federal level next year a little over a trillion dollars, a little over a thousand billion dollars. That breaks down to about $3 billion a day, breaks down to about $1 billion every 8 hours or about $125 million an hour. We are asking to spend $250 million for the SSC next year. That is two hours of the Federal budget.

The United States of America and its consumers will spend more on buying soft drinks today and tomorrow than we are asking to spend for the SSC all of next year. For a project that is going to keep us number one in basic research and number one in the world economic situation today, 2 hours worth of Federal spending is not a big price to bear, in my opinion.

I am skipping over a lot of this because I know the committee's time limits.

To summarize, I would like to quote a Nobel Prize winner from the University of Chicago, Mr. James W. Cronin:

> The spirit of a nation and the pride of its people can only be enhanced when science, including the exploration of our planet, solar system, galaxy, and the universe, is among its highest priorities.

The SSC is not about exploring outer space. The SSC is about exploring inner space, and I think it should be among our highest priorities.

Madam Chairman and members of the subcommittee, I would urge this committee to fully support this essential project.

[The complete prepared statement of Mr. Barton follows:]

TESTIMONY

OF

CONGRESSMAN JOE BARTON
TEXAS, SIXTH DISTRICT

HOUSE SCIENCE, SPACE & TECHNOLOGY COMMITTEE'S
HEARING ON
DEPARTMENT OF ENERGY'S FY 1990 REQUEST FOR
BASIC ENERGY SCIENCE AND GENERAL SCIENCE PROGRAMS

FEBRUARY 23, 1989
2318 RAYBURN

"SUPERCONDUCTING SUPER COLLIDER: A NATIONAL COMMITMENT"

Madam Chairman, I would like to thank you and the Committee for giving me the opportunity to testify today. I wish to testify on behalf of the Superconducting Super Collider (SSC). The SSC Program has received a great deal of national media attention during its two year site selection process. This competitive evaluation initially involved more than 25 states.

As you know, in November of 1988, former Energy Secretary John Herrington announced that the "preferred," and now "official" site for the construction of the SSC is Ellis County, Texas. Not only is this Ellis County SSC site in my home State of Texas, but also in my Congressional District, with part of the proposed ring almost literally located in my own backyard.

Today's hearing begins the Congress' debate on the construction and funding of this project. The SSC will be one of the most important and vital research projects ever undertaken by the United States. It will be the world's most powerful proton-proton collider, producing particle collisions with total energies approaching 40 trillion electron volts, an energy twenty times the highest energies available in existing particle accelerators. I, along with 271 of our House colleagues cosponsored legislation to authorize the project during the 100th Congress. I urge you and your Committee to authorize full contruction funding for the SSC again this year.

Since the emergence of high energy physics as a separate field of research, the United States has led the world. However, I am concerned about losing our preeminence in high energy physics, first to Europe with the Center for European Research-Nuclear (CERN) and perhaps to the Soviet Union with their planned collider called the "UNK." By building the SSC, the United States will maintain its leading position.

Understanding the nature of the world around us will provide research advances of literally cosmic proportions. Funding the Super Collider allows the United States to remain in the forefront of basic science technology for many years to come. Since 1975, American scientists have won half of all Nobel Prizes in physics; however, Europeans have won the last eight. This is a clear indication we are losing our leadership position in high energy physics. If we ultimately lose our leadership position in high energy physics, we will lose our leading edge in world economics.

The SSC will be used by research scientists from around the world and will assure our technological leadership in high-energy physics. If the SSC is not constructed in the United States, future U.S. generations will be forced to buy the technologies of tomorrow from the nations willing to invest in the SSC today.

The development of the SSC will usher in a new era in science and technology, much as the discovery of the electron did 100 years ago. The Super Collider will quite probably provide technical innovations, educational discoveries, new medical treatments and commercial spinoffs undreamed of today. Currently, fully one third of the production making up our gross national product is based on the knowledge of the atom. An investment in the SSC should increase this percentage in the future. I have seen estimates that if the SSC is constructed, superconductivity products could well generate a market of over $10 billion by the year 2000.

Some claim the SSC will adversely affect other research and development projects. Just the reverse is true. Areas such as superconductivity, photonics, robotics and supercomputing will receive increased emphasis because of the SSC. The SSC is the bellweather project for investment in areas of basic research in the "hard" science area and will provide a major boost to the U.S. economy.

The President has advocated doubling the National Science Foundation budget by 1990. I support this increase. The United States must commit the resources to assure initiatives for the continued economic health of future generations. The SSC is not part of this NSF increase, but it is a compliment to that effort. Basic research and development is a valid mission for the federal government to be involved in, and the SSC and the many NSF projects are a major portion of our nation's basic research effort.

As you know, the expected cost of the SSC is $5.9 billion to construct. However, since SSC funding is spread out over many years, the total funding outlay in any given year is relatively modest. The FY 1990 budget request is for a mere $250 million. Based on expected Federal expenditures of over 1.15 trillion dollars, this $250 million is two hours of expected annual Federal spending. When viewed in the overall Federal budget of $1.15 trillion, the funding for the SSC is small indeed.

The $250 million is a realistic figure which will keep the projected full industrial production of the magnets scheduled to begin in 1993 on time. In addition, this figure will give the needed U.S. construction commitment for foreign governments to actively negotiate potential and planned cost-sharing initiatives.

A substantial portion of the SSC funding can come from non-Federal sources. In my state of Texas, voters authorized $500 million in general obligation bonds to help pay for the SSC's construction should it be located in Texas. Texans voted for the bonds because they are dedicated to the United States' scientific excellence, and believe that scientific excellence is necessary to continue economic excellence. Both houses of the State Legislature and the Governor also voiced their commitment with an additional $500 million in funding which makes the total Texas funding package equal to some $1 billion.

Once we in the Congress commit to build the SSC, many foreign governments have expressed a serious interest in cost-sharing. India has agreed to $50 million, and Japan, Taiwan, Korea and several Western European nations have held preliminary discussions with American officials.

Under the current funding schedule, the project can be completed as early as 1996. To meet this ambitious time table, we must authorize the construction of the project this year. Please consider that direct benefits of basic research typically accrue to later generations (i.e. quantum mechanics was developed in the 1920's; the transistor followed in 1947. Nuclear magnetic resonance was discovered in the 1940's; commercial imaging medicine devices followed in the 1970's). We cannot afford to wait on authorizing construction of the SSC this year.

To quote a Nobel Prize winner from the University of Chicago, James W. Cronin: "The spirit of a nation and the pride of its people can only be enhanced when science, including the exploration of our planet, solar system, galaxy, and universe is among its highest priorities."

The SSC should be amongst our highest priorities. I urge this committee to fully support this essential project.

Mrs. LLOYD. Thank you very much, Mr. Barton.
Mr. Chapman.

STATEMENT OF HON. JIM CHAPMAN, REPRESENTATIVE IN CONGRESS OF THE UNITED STATES FROM THE FIRST DISTRICT OF TEXAS

Mr. CHAPMAN. Madam Chairman, thank you, and thank you for your kind words. I already miss your committee and the full committee, and I appreciate the opportunity to be here today to support my colleague, my state but, more importantly, to support an important science project for this country.

As you know, I serve on the Appropriations Committee now, and I am aware that this committee as well as the full Committee on Science, Space, and Technology has in the past Congress expressed overwhelming support for this project.

It is our desire and my message today would be certainly not to discuss the merits of the project. This committee is fully aware, perhaps more than any other in the Congress, of what the super collider is and what its promise may be for this country.

My message to you today is that we need your strong support again this year in an authorization bill so that those who may oppose the project would not be able to use a lack of authorization as some type of leverage down the road to prevent this worthwhile and much needed project from being funded by the federal government.

My colleague, Mr. Barton, has demonstrated the state's commitment that one site competition in excess of a billion dollars for cost sharing.

I met just two weeks ago with officials of the Department of Energy who have ready at this time and are prepared to negotiate foreign participation of hundreds of millions of dollars, perhaps even more, once this committee and the Congress develop and establish the authorization, the policy on cost sharing under which they want the Department to proceed.

Our committee awaits your authorization. We are ready to go to work and support what I think can be a most promising and worthwhile basic science project that we have undertaken in many, many years.

I am here to offer my full support, my assistance, not only for your efforts but our assistance on the Appropriations Committee in funding the authorization that I hope your committee and the full committee will send to the floor of the House.

I appreciate the opportunity to appear here today. I would be happy to answer any questions you may have and look forward to working with you on what I think is a very, very worthwhile endeavor.

Mrs. LLOYD. Thank you very much, Jim. We miss you, but we are also very heartened to know that we have a good friend in the Appropriations Committee as well.

Mr. CHAPMAN. And let me assure you that that friendship extends beyond this project, Madam Chairman, to those other critical projects that——

Mrs. LLOYD. We know that.

Mr. **Chapman** [continuing]. That we have fought together in the past two Congresses to fund.

Mrs. **Lloyd**. We certainly have.

Any questions from members?

Mr. **Morrison**. No questions, and just a repeat of the obvious, and that is the super collision is going to be in the budget process, and so we urge—and I know you are already doing this—the broadest possible base of support for the collider.

I think we have worried on this subcommittee that as we narrowed the focus and got it down to one site that a number of states that were very enthusiastic about it will say it went somewhere else and they don't believe in it any more, and it is much too important for that.

So thank you.

Mrs. **Lloyd**. Congressman Smith.

Mr. **Smith**. Madam Chairman, I would like to thank my colleagues from Texas for their excellent presentations this morning. Congressman Chapman's commitment on the Appropriations Committee to fully fund the SSC is appreciated by us all.

I thought in regard to Congressman Barton's testimony a while ago, the point that the Federal Government would only spend 2 hours of its time if you broke it down on a revenue basis for the SSC points out just how little can go so far, and I would like to say publicly about Congressman Barton that I don't know of anyone who has been more single-minded of purpose or who has done more to promote the SSC than he has, nor do I know of any other lay person who knows more about the technical aspects of the SSC.

I would like to pose one question to both my colleagues from Texas if I could and ask for their explanation, and that is that oftentimes the charge is made that the SSC would certainly benefit Texas economically, but how would the SSC benefit the rest of the country?

And Congressman Barton might want to or Congressman Chapman might want to answer that.

Thank you.

Mr. **Barton**. Well, Congressman Smith, obviously, the SSC project physically will be located in one area. That has to be, but the subcontractors and contractors and scientists that work on the project are going to literally come from not only all over the United States but all over the world.

Congressman Fawell's State of Illinois has got several excellent contractors that are in all probability going to compete for the tunneling contract.

Congressman Lloyd's State of Tennessee has got several scientists in some of the laboratories in that state that will come down and do many hours of excellent experiments at the SSC.

So we talk about one location, but in basic science today it is a world effort, and there is no question that in a project of this scope and of this importance the benefits, the economic benefits and the scientific benefits, are going to be national and international in scope. No question about that.

Mr. **Smith**. OK.

Mr. **Chapman**. I would just add to what Congressman Barton said, Congressman Smith, that the resources upon which the project will draw will be national and international resources. The construction project itself will involve thousands of engineers, staff, employees, and workers from all over America, contractors from as many as probably 25 or 30 states.

So the project itself in its inception, its creation, its construction, as well as of course its promise once it is operational is so much broader than our state that I think we lose, we literally lose sight of what is relevant and what is important when we perceive or even view this project as something that is a Texas project. It is much more than that.

It would be similar to saying that the space program is a Florida project because we launch our shuttles from Florida. We know that is not the case. The spinoffs, the benefits, what we will learn, the young students we will train, the scientists that will keep us innovative and competitive for the generations to come will all be a result of this national project.

We should consider it a national resource because it is.

Mrs. LLOYD. We thank you gentlemen for being with us today, and we know we will hear from you in the future.

Thank you very much.

Our first——

Mr. BARTON. Madam Chairman, with your permission, I would not like to ask any questions, but I would like to listen to the rest of the testimony if that is appropriate.

Mrs. LLOYD. We would love to have you.

Mr. BARTON. Okay.

Mrs. LLOYD. Thank you.

The Chair would like to welcome at this time Dr. Robert Hunter, Jr., who is Director of Energy Research, the Office of Energy Research, Department of Energy.

It is good to have you back again, Dr. Hunter. You were here, I believe, day before yesterday. You are going to be a regular around here. Delighted to have you, and the committee certainly appreciates you not only for your ability, but your dedication to your task.

Please proceed.

STATEMENT OF DR. ROBERT O. HUNTER, JR., DIRECTOR, OFFICE OF ENERGY RESEARCH, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC

Dr. HUNTER. Thank you, Madam Chairman.

It is a pleasure for me to be here, and I would like to make a few brief comments.

Basically, I am here today to discuss the Department of Energy's request for fiscal year 1990 in the area of the basic research programs.

I have submitted written testimony, and with your permission, I would just like to give a few summary remarks.

Mrs. LLOYD. Without objection, your entire statement will be made a part of the record.

Dr. HUNTER. Thank you.

I am here today to discuss several areas that are included in the General Science and Energy Supply accounts. These topical areas include High Energy Physics, Nuclear Physics, Basic Energy Sciences, and educational programs and university support.

Before we go into the details of these different areas, I would like to point out some elements common to the conduct of research in all of these areas.

First, the great bulk of this work is basic research. In basic research, competition among the different researchers leads to utilizing the best means in a given area to obtain the information needed.

Second, the urgency for basic research is not easy to establish. Since the consequences of the information are not explicitly known, we rely on the observation that to produce the best scientists and scientific results you must work in a fashion that forces the pace of advance in an area.

Third, it follows that the scientific communities through a variety of mechanisms for conducting scientific competition, such as advisory and review committees are the basic means for determining the direction and form of research that is to be pursued.

In accordance with these points and to enable these communities to pursue research and assure the highest quality basic research, the Department of Energy relies on the best scientific talent to generate its research programs.

This year, for example, the Nobel Prize in physics was granted to Dr. Leon Lederman, Dr. Schwartz, and Dr. Steinberger, who researched on facilities built and supported by this program. Dr. Lederman has headed the Fermi Lab for many years, also, one of our facilities.

Also, we must continue to invest in new facilities, people, and ideas. We must continue to build new tools, both experimental and theoretical, as part of this process. The efforts conducted under these programs are intended to provide scientific excellence by continuing to utilize existing facilities and critically to provide new facilities to best pursue the different areas' frontiers.

Now, these programs are of benefit to many scientific communities. In today's science, modern communications and transportation have made it possible to build common facilities and common state-of-the-art tools that are used by very many parties. In these programs under discussion we must not lose sight of the fact that even the largest tools are used by many small groups and universities and laboratories dispersed on a national and, indeed, an international scale. Typically, up to hundreds of groups may be involved in one of these large facilities.

In this fashion federal support of science supports and encourages the diversity of expression in competitive science for many parties.

This office, Energy Research, uniquely supports the research itself, the development of facilities, and the support of the facilities for many parties. We have to ensure the optimum utilization of our resources.

Obviously, the development and operation of new tools is a major task and must be undertaken continuously. This year we are building or starting several new large instruments, all of which serve large laboratory and university communities.

These include the SSC, forwarded as the major next step for the high energy physics community, a step of enormous potential and significance; the advanced photon source at 6 to 7 GeV for generating precise high energy X-rays for many user groups simultaneously. We are continuing major construction at CEBAF for the nuclear physics communities, and there are several other projects underway as well.

Let me just highlight a couple of ongoing races that may be of interest to you. One is in X-ray lithography. Developed as part of the basic research facility at Brookhaven National Laboratory, it now appears to be of major interest with regard to the chip making business, and one in high energy physics where our Stanford Linear Collider is just coming online at Stanford, and we expect an exciting race with the Europeans this summer and fall to look for some new particles.

We have to ensure adequate support by the standards that I have discussed with you across the board for university and laboratory groups and across the entire spectrum of basic research. This committee has long been a major and responsible supporter of such research.

In the face of the value of basic research and in the present fiscal environment, the administration shares the determination of this committee to see substantial and real growth in basic research. We believe this is the way to invest in the future.

I would also say that we are appreciative of the support given by this committee to the SSC in the past, particularly the inclusion of funding for 3 years in the fiscal year 1989 authorization bill, and we plan to abide by the guidance in general that was expressed with this bill.

We look forward to working with you to assure the future of basic research and to ensure the continuation and expansion of the areas that I have discussed with you.

I would be happy to answer any questions.

[The complete prepared statement of Dr. Hunter follows:]

Statement of Robert O. Hunter

Director

Office of Energy Research

Department of Energy

before the

Subcommittee on Energy Research and Development

of the

House Science, Space and Technology Committee

February 23, 1989

Madam Chairman and Members of the Subcommittee:

It is a pleasure to appear here today to present the FY 1990 budget request for several of the programs supported by the Office of Energy Research (ER). These programs are: High Energy Physics, the Superconducting Super Collider, Nuclear Physics, Basic Energy Sciences, Energy Research Analyses, University Research Support, University Research Instrumentation, Multiprogram Energy Laboratories-Facilities Support, and supporting program direction.

Funding for these programs in FY 1990 is being requested under the two appropriations shown in Table 1, Energy Supply R&D and General Science and Research. The total FY 1990 budget request for ER's programs is $2.5 billion, an increase of $292 million over the FY 1989 appropriation of $2.2 billion. This request reflects the Department's recognition of the key role played by science in enhancing the economic and technological well-being of the United States, as well as the quality of our lives. It also reflects our continuing commitment to excellence in the programs supported by the Office of Energy Research. I would like to discuss the programs under the General Science and Research appropriation first, followed by those under the Energy Supply R&D appropriation.

HIGH ENERGY PHYSICS

Research in high energy physics pushes beyond the existing frontiers of knowledge about the physical world in which we live. This research not only helps us to learn how our world works, it leads to the development of advanced

Table 1
Office of Energy Research
Summary by Program
Budget Authority
($ in millions)

	FY 1988	FY 1989	FY 1990 Request
Energy Supply R&D			
Basic Energy Sciences	$ 557.7	$ 549.3	$ 590.0
Magnetic Fusion Energy	331.3	350.7	349.2
Biological & Environmental Research	267.1	257.5	271.4
University Research Support	18.2	21.7	16.1
University Research Instrumentation	4.9	5.0	5.0
Energy Research Analyses	3.7	3.8	4.0
Advisory & Oversight Program Direction	3.2	3.3	3.4
Policy and Management	.7	.7	.7
Multiprogram Energy Laboratories-Facilities Support	53.6	55.7	53.0
Small Business Innovation Research	30.1	0	0
Subtotal	$ 1,270.5	$ 1,247.7	$ 1,292.8
General Science & Research			
High Energy Physics	$ 526.1	559.4	616.2
Superconducting Super Collider	33.0	98.6	250.0
Nuclear Physics	242.8	260.9	299.3
General Science Program Direction	2.8	3.2	3.9
Transfer of Prior Year Unobligated Balances	(8.0)		
Subtotal	$ 796.7	$ 922.1	$ 1,169.4
Total ER	$ 2,067.2	$ 2,169.8	$ 2,462.2

technology needed to ensure research progress--technology which, over the years, has had many practical applications in such areas as nuclear medicine, electronics, computer chips, superconductivity, and cryogenics.

The continuing goal of the High Energy Physics program is to improve our understanding of the nature of matter and energy and of the basic forces that govern all processes in nature. High energy physicists search for new knowledge through an interplay of experimental research using accelerators and detectors, and through theoretical studies. The ability to carry out forefront exploratory research on the physics frontier is dependent on many factors including the experimental capabilities of accelerator, colliding beam, and detector facilities; the effective use of those facilities, and the incorporation of upgraded and new facilities on a timely basis to take advantage of new technologies and research opportunities.

Progress in the experimental and theoretical research supported by the High Energy Physics program is also dependent on scientists from over 100 universities who carry out over three-fourths of this research. They provide much of the intellectual leadership for the field along with the scientists from the national laboratories who make up the rest of the experimenters. The High Energy Physics facilities also play an important role in the training of highly skilled scientists and engineers who often contribute significantly to the transfer of technology to other fields.

Our understanding of the nature of matter and energy and the basic forces has grown substantially in recent years; but the search continues for a unified, or single, theory that can explain the connections among the basic forces of nature. The four known fundamental forces are the electromagnetic force, the weak force, the strong force, and the gravitational force. A part of the progress in high energy physics has been the conceptual unification of the weak nuclear force and the electromagnetic force into a single "electroweak" framework. In addition, a theory of the strong force has emerged which is consistent with experimental results. There is increasing anticipation that the unification of the strong nuclear force and the electroweak force into one "grand unified" framework may be possible, thus reducing the apparent number of forces in nature to two. The ultimate goal is a "super-grand" unification that would bring the fourth force, gravity, into the equation, thus bringing all of the forces in nature into a single unified framework.

Based on this progress, scientists have drawn a picture of nature known as the Standard Model which is defined in terms of the electroweak and strong forces and a small set of fundamental constituents present in all matter we see around us. Although the most significant recent experimental results all reinforce the predictions of the Standard Model, scientists believe that it cannot be the final answer. For example, it does not explain the origin of mass and it does not include gravity. Clearly, we do not yet know the final answer to many questions. For instance, have we discovered the ultimate constituents of matter or is there something inside leptons and quarks, which we believe are the fundamental particles. Do we know all the forces of nature and are all of the forces a manifestation of a single force?

Research aimed at answering these questions is currently being carried out at accelerators at three centers supported by the Department of Energy: the Fermi National Accelerator Laboratory (Fermilab). the Stanford Linear

Accelerator Center (SLAC), and the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory (BNL). Each of these laboratories provides world unique capabilities and is operated as a national facility available to qualified experimenters from around the world on the basis of the scientific merit of their proposals. This practice of relying on one-of-a-kind, large, advanced facilities has a long track record of success. The talented physicists attracted by research opportunities at these facilities have continued to produce impressive, Nobel-class research results. Of the two new major U.S. High Energy Physics facilities, the Fermilab Tevatron Collider is now in operation for research; and the Stanford Linear Collider (SLC) has successfully completed a period of accelerator research and is now in the final stages of preparation for physics research. These facilities will keep the U.S. program at the cutting edge for the next several years. To maintain an internationally competitive program at the scientific frontier in the late 1990's, the Superconducting Super Collider (SSC) is being proposed for initial construction in FY 1990. The SSC, which will be discussed later in this statement, is in keeping with the successful High Energy Physics tradition of large, advanced accelerators operated as user facilities that attract the best talent and produce the most promising and exciting research results.

Before turning to a discussion of the FY 1990 budget request, I would like to summarize some of the progress made at the three High Energy Physics accelerator facilities. The Tevatron at Fermilab has been running at world record energy and luminosity in the colliding beam physics run which began in late FY 1988 and will continue into mid-FY 1989. The higher luminosity available at the Tevatron, which exceeds its design by a factor of two, allows scientists to observe a larger number of particle interactions of interest than is possible at the other facilities. During the Tevatron physics run the Collider Detector at Fermilab (CDF) is intensively searching for the as yet unobserved particle known as the top quark. The existence of the top quark has been predicted by the Standard Model. Thus, the top quark search--which puts Fermilab and the European high energy facility, CERN, in a vigorous race for a major discovery--provides a crucial test for this fundamental theory. In fixed-target experimentation at Fermilab, an 8 1/2-month long run was successfully completed in 1988. Eight major experiments were completed; data analysis is in process and physics results will begin to emerge during 1989.

At SLAC, the Stanford Linear Collider (SLC) has reached its first goal of demonstrating that two very small (a fraction of the diameter of a human hair), very high energy beams of electrons and their oppositely charged cousins, positrons, can be brought into head-on collision for a number of hours. The SLC has demonstrated the concept of linear colliders using fifty billion electron volt (GeV) beams and is providing crucial data on the feasibility of the next generation higher energy linear colliders. This concept will likely be the foundation for the next generation of electron-positron colliders. The second goal of the SLC is to study the Z^0 particle, which is the carrier of the weak nuclear force. Commissioning of the SLC to study Z^0 physics is underway, and the SLC is expected to produce several thousand Z^0 particles for study in FY 1989. Detailed study of the Z^0 particle, of which only a few hundred have been observed in the world to date, provides yet another key test of the Standard Model and will shed light on the possible existence of a whole new generation of particles. Also at SLAC, the Time Projection Chamber detector at the Positron-Electron Project (PEP) has just completed its first physics run since the completion of detector and beamline upgrades. The previous record for luminosity has been doubled. Data are now being analyzed with emphasis on measurement of decay lifetimes of short-lived particles.

At BNL, experiments are underway at the Alternating Gradient Synchrotron to study certain rare ways a particle called the kaon decays. The kaon can decay into many different combinations of other lighter particles. Some of these combinations occur very rarely, less than once in three billion ordinary decays. Comparison of experimental results with theoretical predictions will test current theories. The current experiments have already achieved results 10,000 times more sensitive than previous experiments and they offer the opportunity to find experimental evidence for new particles of very high mass. In addition, the AGS multiparticle spectrometer has the best evidence for the experimental identification of an unusual and, as of yet, unseen but predicted particle called a glueball. The quarks inside of protons, for example, are believed to be held together by exchanging an object called a gluon. Theory predicts that if two gluons combine, they would form a glueball. Observation of such objects would provide a new test of the Standard Model.

FY 1990 HIGH ENERGY PHYSICS BUDGET REQUEST

The FY 1990 request for High Energy Physics is $616.2 million. Of the total amount, $492.7 million is for Operating Expenses, $85.5 million is for Capital Equipment, and $38.0 million is for Construction (Tables 2 and 3).

Table 2
General Science and Research
High Energy Physics
Budget Authority
($ in millions)

	FY 1988	FY 1989	FY 1990 Request
Operating Expenses			
Physics Research	$114.4	$121.7	$133.1
Facility Operations	230.1	252.4	277.6
High Energy Technology	63.7	65.1	82.0
Subtotal	$408.2	$439.2	$492.7
Capital Equipment	76.7	79.8	85.5
Construction	41.2	40.4	38.0
Total High Energy Physics	$526.1	$559.4	$616.2

Table 3
General Science and Research
High Energy Physics
Budget Authority
($ in millions)

Construction

Project	TEC	FY 1989	FY 1990 Request
Accelerator Improvements and Modifications (90-R-101)	$14.9	$ -	$ 14.9
Accelerator Improvements and Modifications (89-E-101)	11.7	11.7	-
General Plant Projects (GP-E-103)	13.4	-	13.4
General Plant Projects (GP-E-103)	11.1	11.1	-
AGS Accumulator/Booster (86-R-105)	31.7	14.0	5.0
Fermilab Linac Upgrade (90-R-104)	22.8	-	4.7
Fermilab Central Computing Facility Upgrade (86-R-104)	24.6	3.6	-
Total Construction		$ 40.4	$ 38.0

The Operating Expenses request of $492.7 million reflects strong utilization of existing forefront facilities, particularly the Tevatron proton-antiproton collider and the SLC electron-positron collider. In FY 1990, advanced high energy technology R&D will focus on increasing the luminosity of both the Tevatron and the SLC to maximize the physics output of the existing and new detectors.

The Operating Expenses request also provides for operation at SLAC of the recently upgraded PEP with the improved Time Projection Chamber detector as well as operation at BNL of the Alternating Gradient Synchrotron (AGS) program. The AGS program focuses on rare kaon decay, neutrino and unique polarized proton experiments. Leon Lederman, Director of Fermilab, along with Mel Schwartz and Jack Steinberger, won the 1988 Nobel Prize in Physics for early work on the still very productive AGS.

In keeping with the planned strong use of existing facilities, the Operating Expenses request includes increases for university-based scientists to allow their effective participation in research at these facilities. Funds are also being requested for improvement of the technical capabilities of the university laboratories. The universities play a major role in physics research, detector R&D, and detector fabrication. The requested funds will provide for upgraded instrumentation (e.g., computer-aided design systems, high-speed electronic test equipment, etc.) and broadening and upgrading of the technical support staff at universities.

The FY 1990 Operating Expense request includes funding to support an increased level of technology R&D in support of the operating accelerators, primarily the SLC and the Tevatron. This R&D is crucial in identifying and providing for the modification and improvements needed to maintain the capabilities of the facilities at the cutting edge of the science.

Finally, the FY 1990 Operating Expenses request includes funds to carry out advanced accelerator and detector R&D to develop advanced concepts and technologies. Test-bed verification of some of the most promising of these concepts will be emphasized in FY 1990.

The FY 1990 Capital Equipment request of $85.5 million will provide the particle beam-line components, detection apparatus, and data analysis systems essential to forefront high energy physics research. In FY 1990, priority will be given to completion of the Stanford Large Detector at SLAC and the D-Zero detector at Fermilab. The request also provides for an upgrade of the equipment at the SLAC Central Computing Facility.

The FY 1990 Construction request of $38.0 million includes funds to initiate the Fermilab Linac Upgrade project, a key element in maintaining a vital research program with the Fermilab Tevatron in the years before the SSC becomes operational. This $22.8 million project, with $4.7 million requested in FY 1990, will replace a portion of the accelerator hardware in the existing linac for which commercial replacement parts are no longer available. The upgrade will also result in an increase in the output energy from 200 to 400 million electron volts (MeV). This higher energy produces a smaller beam, better injection, and smaller beam losses in the booster, main ring and

Tevatron thereby increasing the beam intensity and physics output. The Construction request also includes funds for the completion of the Alternating Gradient Synchrotron Accumulator/Booster project at BNL and an increased level of effort for Accelerator Improvement Projects and General Plant Projects to support the accelerator facilities and essential environmental protection efforts.

SUPERCONDUCTING SUPER COLLIDER

The Stanford Linear Collider at SLAC and the Tevatron at Fermilab, which I discussed previously, will keep the U.S. High Energy Physics program at the cutting edge of physics research for the next several years. But even these facilities will not reach high enough energies to allow physicists to investigate the region where major breakthroughs are anticipated. To advance the research frontier a new, more powerful, accelerator is needed. The Superconducting Super Collider (SSC) is that facility.

The SSC will consist of two rings of superconducting magnets and associated systems in a common tunnel, 53 miles in circumference. There will be four interaction regions where two beams of protons will collide head-on, making available a total of 40 trillion electron volts (TeV) of energy. These energies are expected to produce new types of matter and new forms of energy. Large detectors will be used in the interaction regions to detect and record these interactions. The SSC, through its investigation of fundamental physical processes, will provide new insights into questions of great significance to other sciences as well as to high energy physics. The Super

Collider holds the potential for major, new breakthroughs in science and technology, and is expected to produce discoveries, innovations and spin-offs that will profoundly touch every American.

The FY 1990 budget request for the SSC includes funds to initiate construction. This request builds on five years of research, development, and design efforts and careful planning. While the SSC does extend current technology, its design is backed by a thorough conceptual design and is based on principles and engineering concepts used previously. The Super Collider's design, cost estimates, and schedule have been carefully documented and reviewed. The project is backed by an R&D program specifically related to the SSC that began in FY 1984. Prior efforts in the High Energy Physics program to develop accelerator-quality superconducting magnets, and experience gained in the successful operation of the Tevatron, support the SSC design.

A great deal has been accomplished over the last two years as a prelude to the Department's request for construction funds. For example, the superconducting magnets are the largest SSC technical element, with a requirement for nearly 10,000 superconducting magnets costing over a billion dollars. The ability to manufacture these magnets in a cost-effective manner, with stringent quality control and reproducibility, is critical to the success of the project. In December 1988, the Department announced selection of 16 industrial firms and teams for Phase I of the Magnet Industrialization Program which will aid in establishing an industrial capability to produce the nearly 10,000 superconducting magnets needed for the SSC. During Phase I, which began in January 1989, representatives from the selected companies are observing and discussing superconducting magnet fabrication processes, specification requirements, quality control and testing techniques at the laboratories. A second phase of the industrialization program, scheduled to begin in FY 1989, will provide the opportunity for industrial firms to design, tool and fabricate magnets in a demonstration of their capability to manufacture magnets.

In the area of R&D, significant progress has been made with regard to the magnets and the critical superconducting cable. Long magnets have been fabricated and successfully tested, thus demonstrating proof-of-principle of the current design. Production lots of cable which meet SSC specifications, as well as a prototype fast cabling machine, have already been delivered by industry. The magnet cryostat has successfully met the stringent low heat leak goal set for the SSC. An improved design of the cryosystem required to keep the magnets at their super-cooled temperature has been developed in collaboration with industry.

The site selection was completed with the designation of Texas as the final site on January 18, 1989. Since Congress has not yet given approval to the Department's construction request for the SSC, no irreversible actions will be taken at the site during FY 1989. However, the Department will be moving to locate SSC project management personnel at or near the site quickly to ensure that activities required to be conducted at the site can be carried out in a cost-effective manner. A number of actions have been completed or are underway to ensure an efficient transition to near-term site activities. Chief among these is the Department's selection of the Universities Research Association (URA) to build, manage, and operate the SSC laboratory. A contract was signed on January 18, 1989. Site geotechnical studies and gathering of facts for the Supplemental Environmental Impact Statement will begin shortly. A revised conceptual design reflecting the characteristics of the Texas site and the results of R&D since 1986 will be completed in the fall of 1989. This revised conceptual design, which will include a new bottoms-up cost estimate and schedule, will be reviewed and validated by the Department early in 1990. It is also planned that URA will select on a competitive basis an architect engineer/construction management firm (AE/CM) by the summer of 1989. The AE/CM will prepare the detailed facility design and manage the construction of the conventional facility.

The Department continues to seek substantial financial and scientific participation in the SSC from foreign governments in keeping with the goal of seeking approximately one-third of the cost of the SSC from non-Federal sources. Scientist to scientist contacts will be used to define the technical scope appropriate for collaboration. Once areas of collaboration have been defined, official negotiations between governments will follow and may use the framework of existing agreements where possible. In 1988, the Secretary of Energy sent formal invitations for participation to his six counterparts within the Economic Summit countries. The invitations were followed by several rounds of visits from high-level Departmental delegations to provide SSC status briefings and carry out initial consultations with representatives from the Summit countries. The newly extended Science and Technology agreement with India contains a section on possible collaboration on the SSC. This is a provisional annex for in-kind contributions with a value of $50 million. It is important to note that the Indian agreement is contingent upon a commitment of funds to the project by the U.S. government and the settlement of the remaining issue of intellectual property rights in the umbrella agreement.

Significant funding for the SSC project was provided in FY 1989 for R&D, preliminary design, and site selection activities. We expect continuing R&D achievements throughout FY 1989, including definitive progress on refining and optimizing the design of the superconducting magnets, completion of Phase I and initiation of Phase II of the Magnet Industrialization Program, and increased effort on the injectors and other collider technical systems.

FY 1990 BUDGET REQUEST FOR SUPERCONDUCTING SUPER COLLIDER

The FY 1990 budget request for the SSC is $250.0 million. That request includes $69.0 million for Operating Expenses, $21.0 million for Capital Equipment, and $160.0 million for Construction (Table 4).

The Operating Expenses request will provide for a continued significant level of R&D required to complete the design of the superconducting dipole magnets and to expand the magnet industrialization activities, which I discussed earlier, with particular emphasis on enhancing the reproducibility of the magnets and bringing down the unit cost per magnet. The requested funds will provide for extensive design, prototyping and testing of other collider systems, including the focusing and correction magnets. A significant program of detector R&D will also be carried out as this program moves from the generic phase to focus on specific SSC detectors.

Table 4
General Science and Research
Superconducting Super Collider (SSC)
Budget Authority
($ in millions)

	FY 1988	FY 1989	FY 1990 Request
Operating Expenses	$ 33.0	$ 82.6	$ 69.0
Capital Equipment	-	16.0	21.0
Construction (90-R-106)	-	-	160.0
Total SSC	$ 33.0	$ 98.6	$250.0

The Capital Equipment request of $21.0 million will support the R&D activities on the many accelerator components and systems of the collider and its four injector accelerators, power supplies, test and control instrumentation, and components for the magnet test facility. The budget request also provides for prototypes of detector components as SSC experiments and detectors become more completely defined.

The FY 1990 Construction request of $160.0 million would allow initial construction activities to proceed on a broad front. The request includes $29.0 million for detailed design of technical systems, $29.0 million for detailed design of conventional facilities, $8.0 million for power and utilities distribution systems, $8.0 million for site preparations required to support the overall construction project, $20.0 million for injector technical components which are early critical path items, $30.0 million for long-lead, critical path procurements for collider components (including magnet tooling, superconducting materials, and magnet steel), $28.0 million for project management, support equipment and rental space, and $8.0 million to start on the first on-site shop and support buildings.

NUCLEAR PHYSICS

Nuclear processes determine the characteristics of our universe. Thus, an understanding of nuclei and nuclear phenomena is essential to any basic understanding of the world around us. What we are continuing to learn about nuclei and nuclear processes provides the information base for many areas of technology such as nuclear power, nuclear weapons, and nuclear medicine. The applications are varied and range from the diagnosis and treatment of cancer to the use of nuclear techniques for materials testing and geophysical exploration.

Over the years, many theoretical models have been developed to describe the structure of the nucleus and its behavior. Models in which nuclear matter is treated as a fluid (liquid drop model) or an organized collection of nucleons (shell model) have been well developed. Scientists now know that neutrons and protons, the constituents of the nucleus that are called nucleons, are composed of smaller constituents called quarks. These quarks are bound together in tightly knit groups of threes. However, scientists have not been able to isolate quarks outside the nucleus. It is as if quarks were tied together by elastic strings that cannot be broken. This confining mechanism forms the basis of the newest theory of the strong nuclear force, called quantum chromodynamics (QCD). Many aspects of this theory are addressed both by the Nuclear Physics and High Energy Physics research programs. However, only the Nuclear Physics program emphasizes tests of QCD predictions of quark behavior in nuclear matter. In these tests, individual quarks can be isolated and studied within nuclear matter.

The Nuclear Physics research program is carried out at accelerator facilities around the country. Many of these accelerators are located at the national laboratories, including Lawrence Berkeley Laboratory, Argonne National Laboratory, Oak Ridge National Laboratory, Los Alamos National Laboratory and Brookhaven National Laboratory. Others are at universities such as the Massachusetts Institute of Technology (MIT), Yale University, the University of Washington, Triangle Universities National Laboratory, and Texas A&M. In addition, Nuclear Physics research is performed using nuclear physics facilities in combination with the high energy accelerators at Brookhaven and SLAC.

In FY 1988, three new facilities began operation, and a fourth was being significantly upgraded. At Texas A&M, a superconducting cyclotron, constructed entirely with funding from the State of Texas and private foundations, was started up and will accelerate nuclei to moderate energies of around 100 MeV. Using the cyclotron, scientists will study how light nuclei oscillate when they react. In particular, a phenomenon called monopole oscillation will be studied, in which the nuclei expand and contract like a balloon being blown up. Because these nuclei and their reactions are the basis for nuclear fusion in stars (and in controlled fusion reactions), the data gained will be of great interest to astrophysicists.

The new Yale Tandem Accelerator will use medium-mass nuclei at lower energies of around 10-15 MeV to study extreme deformations of nuclei when they are forced together. Study of these dumbbell-shaped nuclei is expected to provide clues to the nature of the nuclear force and the fundamental way in which two pieces of nuclear matter can join together. For even heavier nuclei, the University of Washington's Superconducting Linac Booster will make available energies of up to 25 MeV which will allow study of the modes of oscillation of massive isotopes. The addition of the South Hall Ring experiment to the Bates electron accelerator at MIT will improve scientists' ability to study the spin components of nuclear particles and structures, characteristics vital to understanding nuclear matter.

The Nuclear Physics program in 1988 generated important research results in a number of fields. One of the most exciting areas was in the newly discovered phenomenon of superdeformed nuclei. Ordinarily, nuclei assume a spherical shape. However, in nuclear collisions, medium-sized nuclei such as barium and cerium can send each other spinning. At high spins, the shape of the nuclei changes into an ellipsoidal (football) shape. Surprisingly, in the deformed state, the nucleus seems to act rigidly, not as a spinning drop of fluid. How the collective action of the protons and neutrons within the nucleus gives it this rigid shape is a major question. Further studies of superdeformed nuclei may give clues as to how the shell model, liquid drop model, and other useful pictures of nuclear structure actually fit together.

An even deeper problem is the question of how the quarks are confined within the protons and neutrons that make up a nucleus. The theory of the quark model, quantum chromodynamics, predicts that at high density or high temperature, a phase change will occur and there will be collective or many particle effects--a quark-gluon plasma (QGP). Finding such a plasma would assist us in understanding and confirming QCD, while studying the plasma will greatly deepen scientific understanding of the nuclear force and phenomena in a new scientific regime.

In an attempt to obtain such a plasma, researchers at Brookhaven National Laboratory are accelerating oxygen and silicon nuclei to energies of 14.5 GeV per nucleon. These collisions produce several hundred particles apiece, and detectors of various types are needed to measure them. As expected, experiments to-date have detected no evidence of a QGP, but the data provides confirmation of the underlying theory. This theory predicts that a transition to a QGP may occur at the 14.5 billion electron volts (GeV) per nucleon energy level or perhaps at the higher energies beyond the capability of our present accelerator facilities.

FY 1990 NUCLEAR PHYSICS BUDGET REQUEST

The FY 1990 budget request for the Nuclear Physics program is $299.3 million. Of that total, $205.3 million is for Operating Expenses, $20.0 million is for Capital Equipment, and $74.0 million is for Construction (Tables 5 & 6).

The Operating Expenses request will provide for continued research in low and medium energy physics, in heavy ion nuclear physics and in nuclear theory at approximately the FY 1989 level. This request focuses on current problems of scientific and technological interest and on exploitation of major new facilities. Special emphasis will be placed on effective use of the upgraded accelerators at the University of Washington and Yale University, the Argonne Tandem/Linac Accelerator System (ATLAS) superconducting heavy ion facility, and the Tandem/AGS high energy heavy ion beams at Brookhaven. Adjustments have been made within the program to accommodate the increased interest of students and postdoctoral fellows in nuclear physics, to enhance the theory component, and to concentrate the program on the highest priorities and new scientific areas.

The FY 1990 Operating Expenses request also includes $11.2 million for R&D in support of research on advanced detector concepts as well as the next generation of accelerators, including the Continuous Electron Beam Accelerator Facility and a relativistic heavy ion collider facility.

Table 5
General Science and Research
Nuclear Physics
Budget Authority
($ in millions)

	FY 1988	FY 1989	FY 1990 Request
Operating Expenses			
Medium Energy Nuclear Physics	$ 83.5	$ 85.7	$ 93.7
Heavy Ion Nuclear Physics	64.9	67.5	71.5
Low Energy Nuclear Physics	24.7	25.9	27.4
Nuclear Theory	10.5	10.8	12.7
Subtotal	$183.6	$189.9	$205.3
Capital Equipment	$ 17.7	$ 18.5	$ 20.0
Construction	41.5	52.5	74.0
Total Nuclear Physics	$242.8	$260.9	$299.3

Table 6
General Science and Research
Nuclear Physics
Budget Authority
($ in millions)

Construction

Project	IEC	FY 1989	FY 1990 Request
Accelerator Improvements and Modifications (90-R-201)	$ 4.6	$ -	$ 4.6
Accelerator Improvements and Modifications (89-R-201)	4.3	4.3	-
General Plant Projects (GP-E-300)	4.4	-	4.4
General Plant Projects (GP-E-300)	3.7	3.7	-
Continuous Electron Beam Accelerator Facility (87-R-203)	265.0	44.5	65.0
Total Construction		$ 52.5	$ 74.0

The Capital Equipment request of $20.0 million will improve overall instrumentation for effective use of the research facilities. These funds will provide for such equipment as particle detection systems and data acquisition and analysis systems. The FY 1990 request will also provide for general purpose equipment to meet the laboratory-wide needs of Lawrence Berkeley Laboratory.

The FY 1990 Construction request for Nuclear Physics is $74.0 million. Of that amount, $65.0 million is for the Continuous Electron Beam Accelerator Facility (CEBAF). CEBAF will provide access to the critical transition region between the traditional and emerging descriptions of nuclear matter. The main research tool at CEBAF will be an accelerator with electron beams in the energy range of 0.5 to 4.0 GeV. Its combination of high-energy, high-current, and continuous beam with excellent beam quality is expected to revolutionize the production and collection of data for nuclear physics research.

The FY 1990 Construction funds for CEBAF will be used to begin construction of the experimental area, continue construction of the accelerator enclosure, continue procurement of cavities and cryostats, and begin procurement of arc magnets, power supplies and of experimental equipment.

The Construction request also includes $4.6 million for Accelerator Improvements and Modifications (AIM) and $4.4 million for General Plant Projects (GPP). AIM projects address the need for improvements to research accelerators and related experimental facilities while GPP projects focus on general laboratory facilities. These projects are needed to maintain the scientific effectiveness, reliability, and efficiency of Nuclear Physics facilities.

GENERAL SCIENCE PROGRAM DIRECTION

The FY 1990 budget request for General Science Program Direction is $3.9 million. This request is under the General Science and Research appropriation. The requested funds are required to provide for the salaries, benefits, travel, and other expenses associated with 49 full-time equivalent employees in the Office of High Energy and Nuclear Physics and associated support staff required to administer these programs.

Now let me turn to the programs under the Energy Supply R&D appropriation. The first of these is Basic Energy Sciences.

BASIC ENERGY SCIENCES

The Basic Energy Sciences (BES) program supports the research that provides the fundamental scientific and engineering knowledge needed to underpin advances in DOE's applied technology programs and in industry. In addition to supporting research over a wide range of technical areas, the BES program provides support for the operation of major user facilities such as synchrotron radiation sources, neutron sources, and a combustion research facility. These facilities are national facilities maintained and operated for the benefit of all qualified researchers from Government laboratories, academia, and the industrial laboratories. These facilities are critical to continued progress in the scientific research supported by the BES program; and they are playing an increasingly important role in research carried out by the private sector.

Currently, BES has seven major facilities built and operating. In the past, the demand for time at these facilities has been greater than the time that could be made available. The FY 1990 budget request, which I will discuss later in this statement, provides a more optimal operating level for these facilities and reflects the program's responsibility to plan for the future by constructing advanced scientific facilities which will provide needed new capabilities for conducting forefront research. The 6-7 GeV Synchrotron Radiation Source, which has been rated as a top priority by several science panels, is just such a facility; and I will discuss it in more detail later in my statement.

BES supports about 1,400 individual research projects conducted by about 4,000 scientists at more than 200 separate institutions. The BES program undertakes research primarily at national laboratories and universities and, to a lesser extent, at private research laboratories and other Government laboratories. Approximately 60 percent of BES-supported research is carried out at national laboratories. Since these laboratories are also involved in many aspects of the applied energy programs, they are skilled at facilitating transfer of scientific information and technology from experiment to application. In addition, the stability of the organization and the specialized capabilities which exist at the laboratories in many instances are unmatched. The BES program also provides significant direct funding support to universities in addition to providing them with research time at the various user facilities located at the national laboratories. BES also provides funding for the supercomputer centers used by other ER investigators as well as BES researchers. All of these BES-supported activities play a major role in training future scientists.

In addition to universities and national laboratories, BES supports research in and maintains strong ties with industry. Representatives from different industries serve on the BES Advisory Committee; experts from industry participate in the review of research proposals and use the specialized facilities sponsored by BES; industrial scientists participate in advisory committees to the national laboratories; and industry representatives are invited to attend BES conferences and workshops on special topics.

The FY 1990 budget request for Basic Energy Sciences is $590.0 million (Table 7). The request includes $470.7 million for Operating Expenses, $37.6 million for Capital Equipment, and $81.7 million for Construction.

The request for Operating Expenses will allow us to conduct research aimed at uncovering new energy-related information in materials sciences, chemical sciences, applied mathematical sciences, engineering and geosciences, energy biosciences, and advanced energy projects. The funds are necessary to provide for continuation of the core research programs at the present level, expanded research activity in high temperature superconductivity and molecular sciences, and continued operation of the important national scientific user facilities. These funds will also provide for research and development required for further progress on planned new advanced scientific facilities such as the 6-7 GeV Synchrotron Radiation Source, which will provide hard

Table 7
Energy Supply R&D
Basic Energy Sciences
Budget Authority
($ in millions)

	FY 1988	FY 1989	FY 1990 Request
Operating Expenses			
Materials Sciences	$ 170.4	$ 180.5	$ 202.3
Chemical Sciences	127.2	132.9	147.9
Applied Mathematical Sciences	41.9	42.7	44.9
Engineering and Geosciences	31.0	33.2	34.1
Advanced Energy Projects	14.1	14.5	14.9
Energy Biosciences	20.0	20.6	21.2
Program Direction	4.5	4.9	5.4
Subtotal	$ 409.1	$ 429.3	$ 470.7
Capital Equipment	31.7	31.7	37.6
Construction	116.9	88.3	81.7
Total Basic Energy Sciences	$ 557.7	$ 549.3	$ 590.0

X-rays for frontier research in a variety of areas including the surface characteristics of materials, the structure of biological materials, and angiography.

I would now like to describe briefly some of the research activities and results of each of the major BES subprograms. In FY 1990, research in Materials Sciences will continue to increase our understanding of the properties and behavior of materials. Materials often are the limiting feature in energy systems because they often prevent higher temperatures and efficiency and shorten the lifetime of systems. Conversely, advances in materials frequently provide new opportunities, which can ultimately result in entirely new technologies, such as high temperature superconducting instruments and electrical machinery. These technologies in turn depend on the discovery and development of suitable superconducting materials.

BES-supported Materials Sciences research concentrates on selected areas of importance and on areas where problems are known to exist or are anticipated. Some research may relate to a single energy technology (such as research on photovoltaic materials for converting solar energy to electricity); some applies to many technologies (such as research on corrosion mechanisms in materials); and still other work has more fundamental implications for all materials research (such as research on interfaces in solids and computer modeling of materials phenomena).

During the past year, Materials Sciences continued to make substantial progress on the new high temperature superconductors. Researchers at Argonne National Laboratory were able to isolate a pure compound in the bismuth-strontium-calcium-copper-oxygen mixture which was superconducting at a temperature of -163 degrees Centigrade. Previously, similar results occurred at temperatures of up to only -188 degrees Centigrade. This was also an especially noteworthy achievement because this compound does not include any of the expensive rare earth elements.

In another accomplishment related to superconductivity, scientists at Sandia National Laboratories successfully prepared the first thin films of the new thallium-based superconducting materials and showed that they can carry high critical currents which are not easily destroyed by a magnetic field. This is important because the goal is to achieve sufficiently high currents without exceeding the critical level, because to do so would eliminate the superconducting effect.

Synchrotron radiation sources and neutron sources supported by BES continued to be used by the national scientific community to determine the structure of the many high temperature superconductors which have been discovered. Other advances in Materials Sciences included work on enhanced methods for forming structural ceramics, a class of materials which have potential for use in such applications as automobile engines. Researchers also developed computer models of structural features called grain boundaries, which often are the weakest area in a material.

In Chemical Sciences, research supported in FY 1990 will continue to expand our knowledge, with a long-term goal of creating new or improved processes for using and converting energy resources. The focus of the research is on the chemical properties of matter and the interactions of the component molecules, atoms, ions, and electrons. Research in some areas, such as chemical catalysis, where scientists seek a better understanding of why some molecules uniquely promote specific chemical reactions, may be quickly exploited by industrial process designers. Research in other areas, such as the use of light-induced chemical reactions to produce hydrogen from water decomposition, may not find practical application for a number of years. Still other research areas, such as the study of the interactions of atoms and electrons with plasmas, may produce knowledge important in the development of entirely new energy technologies.

Chemical Sciences research ultimately affects such areas as production of fuels and chemicals from coal, nuclear waste separation, conversion of biomass (such as wood and leafy materials) into liquid fuels using enzymes or micro-organisms, and detection and measurement of harmful byproducts of energy processes. One research area that will continue to receive emphasis in FY 1990 is coal science. Scientists are working to understand the structure and chemical reactivity of coal. Such understanding will aid in developing new ways of transforming coal into synthetic gaseous or liquid fuels. A second principal focus in FY 1990 will be on combustion. With world energy production still overwhelmingly based on fossil fuels, control and reduction of pollution depends largely on improving the efficiency with which such fuels are burned. To do this requires a broad and basic understanding of the complex process of combustion. The FY 1990 Operating Expenses request will also provide for the study of heavy elements and the production and separation of heavy radioactive elements. These latter areas are of great importance to radioactive waste disposal programs.

During the past year, research in Chemical Sciences demonstrated for the first time a new measuring technique which is capable of providing direct information about the structure of molecules on surfaces. Also, scientists have confirmed a theory concerning the existence of the Antarctic ozone hole which improves our understanding of the effects of chemical pollutants on changing atmospheric conditions. Other accomplishments include development of new, high-power lasers for use in scientific research, improved models for predicting the behavior of coal solutions, and the discovery of a new method of using electric fields to stir liquids in chemical separations processes, thus increasing the efficiency of extracting the desired chemical and significantly reducing energy consumption.

Research in Engineering and Geosciences encompasses two broad disciplines. The first, engineering research, aims to enlarge our knowledge of the processes and concepts that underlie current engineering practice in energy technologies. Although fundamental engineering research is aimed at long term goals, important near-term applications have emerged from the work supported. For example, the Department has supported research into new optical theories that aim to maximize the intensity of light over an area, rather than to produce a sharply focused image. Such theories recently have allowed the Department's solar energy program to construct solar furnaces that concentrate the sun's light by 50,000-fold, a tripling of previous performance. This gives light intensity nearly equal to that at the sun's surface. One possible application is to power lasers for communication from satellites. The increased intensity now possible would reduce the problem of energy losses encountered when sunlight is converted to electricity.

Research in geosciences contributes to a better understanding of the energy-related aspects of geological, geophysical, and geochemical processes related to the earth. Several geoscience research projects that will continue in FY 1990 involve advanced methods for remote sensing and measurement of the properties of earth materials as well as direct scientific drilling to study the thermal zones of the earth and those bearing fossil fuels. For example, high resolution underground acoustic imaging is being developed to illuminate, in detail, the characteristics of groundwater and petroleum reservoirs.

In another geosciences project, drilling was started in July 1988 in the Valles Caldera, New Mexico, on the tenth Continental Scientific Drilling Project funded by DOE. This 5,780-foot hole is now complete and is the deepest fully cored hole in a geothermal area thus far drilled in the United States. The project, which will continue in FY 1990, will study boiling, heat transfer, and ore deposition in thermal zones of the earth.

Applied Mathematical Sciences supports long-range mathematical and computational research. Computational methods provide insights into experimental data and simulate ideal experiments for testing analytical models. This subprogram advances all aspects of scientific computation--from proofs of theorems about mathematical equations to understanding the structure of parallel computer systems.

In 1988, scientists at Sandia National Laboratories in Albuquerque discovered new methods for solving complex scientific problems at unprecedented speeds. They developed innovative methods for parallel computing for the

1,024-processor hypercube computer at Sandia and demonstrated speedups over single-processor computing near the theoretical limit on full-scale applications in wave propagation, solid mechanics, and fluid flow research.

In addition to supporting mathematical and computational science research in FY 1990, Applied Mathematics Sciences will provide access to scientific supercomputers which are essential for researchers supported by the Office of Energy Research in high energy and nuclear physics, basic energy sciences, and biological and environmental research.

Energy Biosciences research in FY 1990 will continue to increase our understanding of basic biological principles, biological mechanisms, and organisms useful for energy applications, such as the production of fuels from biomass materials. Other possible applications include biological processes that might substitute for energy-intensive activities, such as fertilizer production, and biological means of resource recovery, such as the extraction of copper from ore through leaching. This research activity consists principally of research in the plant and microbial sciences.

One recent research accomplishment concerns a small plant, Arabidopsis, that is having a profound effect on plant science research since recent DOE-supported research showed how easily mutations in the plant could be induced, recognized and employed for studying many different plant processes. As a result, Arabidopsis is now the most commonly used plant system for basic biological research. The studies are done using molecular biological techniques. The most important aspect of this discovery is the ability it gives us to identify and subsequently transfer genes having agronomic importance from Arabidopsis to certain crop plants. An example of this would be the transfer of herbicide resistance genes. Ultimately, the biotechnology industry may be able to take advantage of this ease of mutation to produce much improved plants.

The results of microbiological research about fermentations, plant-microbe interactions, and the microbial degradation of plant material will be the foundation of new biosystems capable of producing fuels and chemicals. Bacteria may be able to do work now done by energy-consuming industrial processes. Recent studies in this direction have involved sulfate-reducing bacteria that convert the sulfur in sulfuric acid to hydrogen sulfide. Recently, scientists have discovered a virus that can transfer genetic material between different strains of these sulfate-reducing bacteria. This opens up the possibility of tailoring these bacteria to perform such tasks as removing sulfates from waste streams. Genetically altered, sulfate-reducing bacteria provide insights into bacterial conversion processes applicable to many industrial applications, to bacterial-induced corrosion processes and to preservation of oil wells, where hydrogen sulfide production interferes with drilling operations and ultimately in the oil refining process itself.

The main objective of Advanced Energy Projects is to explore the feasibility of novel energy-related concepts evolving from basic research that are at an early stage of scientific definition and therefore not yet of practical use to technology programs. Although these concepts involve a high degree of risk, they have the potential for high payoffs. Thus, Advanced Energy Projects fills a void, encouraging the transition of basic research results into technological applications. It also supports exploratory projects that do not precisely fit into any single program area but that have broad potential applications.

Recently a small company, ParaMagnetic Logging, Inc., which is supported by Advanced Energy Projects, established the feasibility of a new technique to be used for locating oil and gas deposits overlooked in existing reservoirs. Previously, it had been impossible to systematically locate such deposits without drilling expensive new holes. The oil and gas industry now uses measurements of the electrical resistivity of geological formations to determine the presence of oil and gas in newly drilled holes. However, such measurements have been impossible to make through steel pipes that surround wells in existing older oil fields. The company has developed a new technique that will allow such measurements to be made, thus resulting in the detection of "missed oil" and "by-passed gas." This technology has the potential to significantly increase the proved oil reserves within the United States.

Advanced Energy Projects also supports research on heavy-ion accelerators aimed at validating this technology as an inertial fusion driver. Heavy-ion beams could be the ultimate choice for generating energy from inertial fusion if issues associated with accelerating beams to the required intensities are successfully resolved with cost-effective accelerator designs. Scaled experiments aimed at addressing these issues are underway and will be continued.

As I mentioned earlier, the operation of major user facilities is a very important part of the BES program. At the present time, BES has seven major facilities: the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL); the Stanford Synchrotron Radiation Laboratory at Stanford University (SSRL); the High Flux Beam Reactor (HFBR) at BNL; the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory; the Intense Pulsed Neutron Source (IPNS) at Argonne National Laboratory; the Los Alamos Neutron Scattering Center at Los Alamos National Laboratory; and the Combustion Research Facility at Sandia National Laboratories (Livermore). It is important to keep the facilities operating at levels which are responsive to the demand for their use; and the FY 1990 budget request is consistent with this goal.

During the past year, many new and interesting results have come out of research at these facilities. For example, at SSRL, synchrotron radiation was demonstrated to be effective in imaging the coronary artery circulation of human subjects. Clinical research in this area will now move to the NSLS because of the higher flux of radiation available there. Also at the NSLS, lithography experiments by IBM have led to full-scale working computer chips with feature sizes as small as one-half micron, which is one thousandth of a millimeter. The success of these has made synchrotron radiation a leading candidate for fabricating computer chips with feature size at or below one-half micron. At the IPNS and the HFBR, neutrons were used to uncover the structure of the new high temperature superconductors.

The HFIR has been undergoing reviews and modifications since the pressure vessel was observed to have higher than expected radiation embrittlement in November 1986. These reviews are now nearing completion and a plan has been established for restarting the reactor using lower pressure, higher temperature, and lower power.

The BES Capital Equipment request for FY 1990 is $37.6 million. These funds will ensure that BES-supported researchers will continue to have the equipment needed to initiate and continue advanced research, much of which involves experiments at extremes of temperature and pressure. Reliable, precise measurements under these conditions challenge the current state-of-the-art. Replacements and new equipment funded under this request, which are important to the continued success of the program, include such items as electron microscopes, neutron spectrometers, molecular beam equipment and computers for equipment control and data analysis.

In addition to its seven facilities, BES is constructing advanced scientific facilities which are critically needed by the scientific community. A substantial part of the FY 1990 construction request of $81.7 million for BES (Table 8) is for the 1-2 GeV Synchrotron Radiation Source at Lawrence Berkeley Laboratory and the 6-7 GeV Synchrotron Radiation Source at Argonne National Laboratory. Both facilities are needed to cover the entire radiation range needed for experiments supported by the program. The 1-2 GeV project is a third generation light source in the vacuum ultra violet/soft x-ray range. The FY 1990 request includes $26.0 million for this project, for which construction was begun in FY 1987. The 6-7 GeV project is a new hard x-ray synchrotron light source which has been rated as top priority by several

Table 8
Basic Energy Sciences
Construction Summary
($ in millions)

Project Title	FY 1989	FY 1990 Request	TEC
Neutron Scattering Experimental Hall (LANL)	$ 4.0	$ 0	$ 17.5
1-2 GeV Synchrotron Radiation Source (LBL)	25.0	26.0	99.5
3 GeV SPEAR Injector (SSRL)	6.5	4.5	14.0
6-7 GeV Synchrotron Radiation Source (ANL)	6.0	40.0	456.0
General Plant Projects	4.9	5.6	5.6
Accelerator Improvement Projects	2.3	4.6	4.6
Partial Decontamination and Medium Term Protective Storage of the ANL CP-5 Research Reactor	0	1.0	5.4
Congressionally Initiated University Projects	39.6	0	0
Total Basic Energy Sciences Construction	$ 88.3	$ 81.7	

science panels, including one from the National Academy of Sciences and one from the DOE Energy Research Advisory Board. Funding for design only was included in the FY 1989 appropriation. The FY 1990 Construction request includes $40.0 million for initial construction.

Now let me turn to the several ER programs that are related to my statutory responsibilities to advise the Secretary on DOE's research and development programs, on the non-weapons multiprogram laboratories, and on the education and training of scientists and engineers.

ENERGY RESEARCH ANALYSES

The technical assessments and research analyses carried out under the Energy Research Analyses (ERA) program cover all aspects of the Department's civilian R&D programs. These in-depth reviews provide information on the quality of the research and its impact, as well as on opportunities for future research. In addition, the program plays a key role in coordinating the Department's involvement in acid rain research. Specifically, the program provides funds under the National Acid Precipitation Assessment Program (NAPAP) for summarizing the state-of-the-science in acid rain research and producing assessment reports useful for policymakers.

The FY 1990 budget request of $4.0 million will provide funding for peer reviews of projects in the Office of Energy Research and also in Conservation and Renewable Energy, and Fossil Energy. It will also provide for technical assessments which will be performed in areas such as advanced polymer composites, corrosion, and plastics recycling. In addition, funds will be provided to help complete the final NAPAP Assessment, including support for synthesizing the results of over $500 million worth of Federally funded acid rain research through FY 1990.

UNIVERSITY RESEARCH SUPPORT

The Nation's colleges and universities produce much of the new scientific knowledge and technical talent that ultimately contributes to the Nation's economic and social progress. For this reason, the Department supports close interactions with the Nation's universities through direct support for on-campus research, collaborative efforts involving DOE laboratory scientists and facilities, and the specific research and science education-related programs that I will discuss next, the University Research Support program and the University Research Instrumentation program. These programs help strengthen university capabilities to perform long-range R&D, contribute to the quality and numbers of young people pursuing energy R&D careers, and enhance technology transfer to the private sector.

The FY 1990 budget request for the University Research Support (URS) program is $16.1 million. The four URS activities include Laboratory Cooperative Science Centers, R&D Laboratory Technology Transfer, University Reactor Fuel Assistance, and Energy Manpower Development (Table 9).

The first URS subprogram, Laboratory Cooperative Science Centers, includes support for faculty and student research and training appointments at the DOE laboratories. The essential roles played by the Department's laboratories in assisting in university research and manpower development have been strongly

Table 9
Energy Supply R&D
University Research Support
Budget Authority
($ in millions)

	FY 1988	FY 1989	FY 1990 Request
Operating Expenses			
Laboratory Cooperative Science Centers	$ 13.6	$ 15.4	$ 9.4
R&D Laboratory Technology Transfer	1.1	1.4	1.7
University Reactor Fuel Assistance	1.7	2.2	2.3
Energy Manpower Development	1.8	2.7	2.7
Total University Research Support	$ 18.2	$ 21.7	$ 16.1

endorsed in reports of the Energy Research Advisory Board (ERAB) and White House Science Council on the health of U.S. colleges, universities and industry. The recent ERAB report to the Secretary on the Department's role in science education (August 1988) states that "perhaps the Department's greatest contribution to education is in providing a link between universities and the laboratories." Consistent with these analyses, the URS program continues to provide expanded support for lab-based education activities. A major initiative begun in FY 1988 provides support for semester-length appointments for undergraduate science and engineering students selected nationally based on academic merit and future research interests. These appointments will be provided to approximately 450 students and to about 36 faculty/student research teams at six laboratory science centers. Support will also be provided for some 2,000 summer faculty/student research appointments.

It is broadly accepted that person-to-person interactions are the keys to successful technology transfer. The R&D Laboratory Technology Transfer subprogram aims to make the results of Federally funded R&D more widely available in the marketplace by cost-sharing the assignment of industry scientists at multiprogram and major single-purpose laboratories and by supporting pilot technology transfer initiatives. In FY 1990, 30 industry-laboratory technology exchange assignments involving personnel from both large and small companies will be funded.

University Reactor Fuel Assistance provides support associated with the fabrication and shipping of nuclear fuel for university-based nuclear research and training reactors. The FY 1990 budget request will provide for refueling five reactors and will fund 20 reactor sharing research awards involving scientists from more than 50 universities. Continued support also will be provided to the low enriched uranium (LEU) reactor fuel conversion program required by the Nuclear Regulatory Commission. By FY 1990, 11 nuclear reactors will have either converted, or will be in the process of converting, to LEU.

DOE, along with other science agencies, depends on a continual flow of new, highly educated scientists and engineers for its current and future programs. The last URS subprogram, Energy Manpower Development, carries out a number of activities directed at increasing the number of young people pursuing energy-related scientific and technical careers. For example, the FY 1990 budget request will support approximately 23 Pre-Freshman Engineering projects reaching 2,200 students, as well as seven high school science student honors programs. The latter will be conducted at the Lawrence Livermore, Brookhaven, Argonne, Lawrence Berkeley, and Oak Ridge National Laboratories, Fermi National Accelerator Laboratory, and the Pacific Northwest Laboratory. At least eight DOE laboratories, including the seven I just mentioned and Los Alamos National Laboratory, will also sponsor summer research programs for approximately 150 high school science teachers selected on a national basis.

UNIVERSITY RESEARCH INSTRUMENTATION

University scientists conducting research for DOE need access to state-of-the-art research instrumentation. The Department's University Research Instrumentation (URI) program helps universities acquire the state-of-the-art instrumentation that is needed to conduct long-range research on energy problems. In the process, the program provides graduate students with hands-on experience in the use of this sophisticated research instrumentation. This annual, competitive program involves substantial cost-sharing from the institution receiving the equipment. Each year the Department's program managers help select the high priority energy topic areas that are to be emphasized in the URI program announcement. The annual awards are based on merit, the accomplishments of current DOE-supported research projects, and the degree to which the new equipment will enable researchers to substantially advance the understanding of energy-related phenomena.

The FY 1990 budget request of $5.0 million for the URI program will assist universities in purchasing instruments that cost over $100,000 each and that will be used by a number of researchers, including students. In selecting approximately 20 proposals to be funded, special emphasis will continue to be given to the need for innovative instrumentation needed to carry out research on advanced topics in energy research.

MULTIPROGRAM ENERGY LABORATORIES-FACILITIES SUPPORT

The goal of the Multiprogram Energy Laboratories-Facilities Support (MEL-FS) program is to reduce facility deficiencies and maintain safe, cost-effective, environmentally clean and productive operations at the five national laboratories overseen by the Office of Energy Research. To accomplish this, the MEL-FS program supports activities that counter problems of aging and obsolescence of facilities and of environmental compliance.

The MEL-FS program consists of two subprograms. The General Purpose Facilities Construction subprogram originated in FY 1981 as a broad program for rehabilitation, upgrade, or replacement of deficient buildings, utilities, roads, railroads and other related facilities at the laboratories. The Environmental Compliance subprogram originated in FY 1985 to address environmental deficiencies at Oak Ridge National Laboratory.

The FY 1990 budget request for MEL-FS is $53.0 million (Table 10). Of this amount, $32.5 million is for the General Purpose Facilities Construction subprogram. This request will provide for 26 construction projects, of which many are environmental, safety and health related improvements.

The FY 1990 request for the Oak Ridge National Laboratory Environmental Compliance subprogram is $20.5 million. Of the total request, $9.0 million is for Operating Expenses and $11.5 million is for Construction. The request for Operating Expenses is necessary to continue to characterize and investigate current waste handling and environmental control systems, leading to upgrades of these systems, and to continue remedial investigations and feasibility studies on previously contaminated sites. The Construction request will provide for continuation of a high priority project to upgrade a portion of the liquid low-level waste collection and transfer system at ORNL and initiation of a few minor general plant projects designed to correct deficiencies in operating systems. This subprogram is focused on bringing operational systems up to current environmental standards.

Table 10
Energy Supply R&D
Multiprogram Energy Laboratories - Facilities Support
Budget Authority
($ in millions)

	FY 1988	FY 1989	FY 1990 Request
General Purpose Facilities			
Construction	$ 28.5	$ 31.2	$ 32.5
Environmental Compliance-ORNL			
Operating Expenses	12.9	8.8	9.0
Capital Equipment	.4	.3	0
Construction	11.8	15.4	11.5
Total Environmental Compliance	$ 25.1	$ 24.5	$ 20.5
Total Multiprogram Energy Laboratories-Facilities Support	$ 53.6	$ 55.7	$ 53.0

ADVISORY AND OVERSIGHT PROGRAM DIRECTION AND POLICY AND MANAGEMENT

The FY 1990 budget request for Advisory and Oversight Program Direction is $3.4 million. The FY 1990 request will provide the staffing resources required by the Director of Energy Research to carry out his responsibilities under legislation (P.L. 95-91) and those assigned or delegated by the Secretary in areas beyond the scope of other ongoing Energy Research programs. These funds are required to provide for the salaries, benefits, travel and other expenses associated with 44 full-time equivalent employees.

The FY 1990 request for Policy and Management is $0.7 million. These funds are required to provide for the salaries and related expenses associated with 8 full-time equivalent employees in the Office of the Director of Energy Research.

That concludes my statement. I would be happy to answer questions.

DISCUSSION

Mrs. LLOYD. Thank you very much, Dr. Hunter.

Those of you in the back, I think we do have some chairs around this way if you would like to be seated.

We are going to be abiding by the 5-minute rule, including this Chair, this morning.

Dr. Hunter, does the Bush budget differ from the Reagan budget in the areas of basic energy science or general science research? Where are we?

Dr. HUNTER. No, ma'am, it does not.

Mrs. LLOYD. We don't——

Dr. HUNTER. No.

Mrs. LLOYD [continuing]. Have any numbers to indicate that there will be a difference? Has the Bush Administration given you any indication of whether or not they have the strong support behind SSC as the Reagan Administration has?

Dr. HUNTER. Well, yes, ma'am, certainly in the budget message itself and in the way the project has been received and discussed in the Department there. I believe that they are firmly committed to it.

Mrs. LLOYD. As you know, there are several construction initiatives that are underway or proposed, and these include, as you mention in your testimony, the advanced light source at Lawrence Berkeley, advanced photon source at Argonne that I recently visited, the advanced neutron source at Oak Ridge, and then RHIC at Brookhaven, and we also need to make sure that CEBAF is completed, and we hope this is without additional delays because you know these delays are very costly.

My question is how can we do this and keep the construction schedule of SSC?

They are all initiatives, as you know, this committee supports.

Dr. HUNTER. Well, I have indicated to you the basic criteria, that you need the facilities to let you look. You need to keep building new kinds of facilities to look in the areas you are looking for the frontier information. You need to build facilities and conduct research at a rate to let you force the pace of development, and you need to be able to involve very large communities of scientists throughout the country in that work and afford them diversity.

Using those basic criteria, what you see here is that you have the SSC, which has been looked at carefully by the entire high energy physics community since 1982 and is essentially the unanimous choice, as recently confirmed this month by the High Energy Physics Advisory Panel as the way to go in the long term for high energy physics, and they have also looked at making sure that they can operate the other facilities during the time period of the construction of the SSC and conduct good physics work during that period of time.

So I think that what you see here is that is the way the people want to proceed in looking at the most fundamental pieces of nature, if you will.

In the area of nuclear physics we have CEBAF, which is fully funded. We intend to proceed ahead and get it finished. It is on schedule in cost, and that is a major facility for nuclear physics.

This at the moment is around—a little bit under one-third completed.

With regard to RHIC, specifically, it was not quite as high in priority because it was the second major facility this year in nuclear physics, and it can come on. We can start construction in a few years, within the next few years, and still be able to force the pace of advance in the nuclear physics area.

So we are very supportive of RHIC and anticipate that it will go forward.

In the area of facilities such as the light sources and the neutron sources, they are used primarily—not exclusively in the case of the light sources—but primarily for condensed matter physics, and they are the tools of choice for exploring condensed matter physics and some surface physics areas.

There we have many facilities under construction. We have undertaken a development line on the synchrotron rings, in which several have been built in this country in the last few years and we have a major construction start this year, to be built at Argonne National Laboratory, in the advance photon source for an even brighter and higher energy X-ray ring with 50 to 100 separate user groups, and we think that is necessary because we basically want to keep forcing the pace of development in that area.

With regard to the neutron scattering, the X-ray scattering in the last 5 to 10 years has come to strongly supplant and supplement neutron scattering for understanding condensed matter physics, and so what you see here is a variety of tools. We have spent a great deal of energy recently trying to ensure the continued operation of the existing reactors that we have, and we feel that we can assure a plentiful supply of neutrons and the photons, if you will, with the budget you see before you.

So in short, we have looked at the different areas. The communities have evaluated through their advisory committees and for long periods of time on these projects because clearly one thing we want to make sure is that the projects are disciplined. They have to come in near budget and on schedule because you don't want them cutting into the basic research you are also supporting in the same area. It is just of critical importance.

So we are going through those processes and as, for example, the advanced neutron source evolves to the point where we understand the costs clearly and the need becomes more expressed, then I am sure we will be moving forward with it.

But the budget you see before you, by the general criteria that I outlined to you, are what we feel is needed to maintain the excellence of the basic research enterprise here in this country, and we view the SSC as certainly a major initiative. It is a very large initiative, but it will involve literally hundreds of groups from throughout the country and the world. It is there as a facility to provide frontier information for thousands of physicists, and so given that the community itself chose it as the mechanism they wanted to use to best explore high energy physics, the Reagan and now the Bush Administration have forwarded and strongly supported this initiative on that basis.

Mrs. Lloyd. Thank you very much. My time has expired.

Mr. Morrison.

Mr. **Morrison**. Dr. Hunter, I am very interested and concerned in the isotope production area and wondered if this budget advanced any sort of a plan to supply medical and industrial isotopes from both HFIR and FFTF.

Dr. **Hunter**. In the plan before you, we have counted on getting HFIR restarted and back into operation. We believe we are very close to that. HFIR, as you know, was originally designed to provide certain kinds of isotopes, particularly californium, that required a very high neutron flux in the center region, and it has, associated with it at Oak Ridge, the chemical pipeline, if you will, that handles the isotope, separates it, and puts it in a form that can be packaged and then dealt with to users.

We have received a lot of indications of concern over the interruption in the supply, which is the major reason we put the effort in to try to restart the reactor. So we plan to bring the isotope operations associated with HFIR back up in the immediate future.

In terms of the FFTF, I do not know the details. I understand that there has been discussions with regard to the use of FFTF for isotope production but that the integrated chemical handling, if you will, and processing was going to perhaps be done at Oak Ridge and it would have that capability.

But I do not know the details. In the Basic Energy Research area the only support that we have is associated with the HFIR and with the associated operation and production of isotopes there.

Mr. **Morrison**. If FFTF is selected as the ongoing producer of plutonium 238 for the space program, there is still room in the machine for isotope production; is that accurate?

Dr. **Hunter**. I can't answer that, sir.

Mr. **Morrison**. I am confident it is.

OK, thank you. I appreciate the answer.

Mrs. **Lloyd**. Mr. Fawell.

Mr. **Fawell**. Thank you, Madam Chairman.

Mr. Hunter—Dr. Hunter—excuse me—I have just a little question here. Being Duncan's brother, do you think that will hurt at all in your capacity? Being Duncan's brother, do you think that will hurt at all being in your capacity?

Just a joke. It isn't meant to be serious at all. [Laughter.]

We all respect Duncan very, very much.

Dr. **Hunter**. Well, I hope you don't want an answer, sir.

Mr. **Fawell**. The one question I had was in reference to the SSC and in the cost, about which we are all concerned, what about the foreign participation and what portion of the total cost, say, of 5.9 would you envision would be taken up by foreign investment?

Dr. **Hunter**. In our discussion of the budget we have referred to nonfederal contributions. We were quite pleased to see the magnitude of the contribution alluded to by the people here earlier from Texas, which is quite substantial.

Secondly, we have received—in the case of India we actually have a signed agreement for, I think, some $50 million over the course of the program, and we have received a letter of strong support from Korea and are having discussions with many other countries.

The way I would describe the situation is as follows:

With regard to use of collaborations in the international area for the detectors, this is a very normal, straightforward and customary activity that takes place in these large accelerators historically. We see those collaborations forming on the next 1 to 2-year time frame. They are just now beginning to form, and so we hope to understand within one to two years precisely what that contribution would be.

But if we extrapolate from our previous experience, both our contributions overseas and the contributions overseas here, I think several hundred million dollars is a minimum number for contributions in that arena.

Mr. MORRISON. In the detectors?

Dr. HUNTER. The customary detector involvement of foreign parties.

Now, the other area that arises is in the area of actual construction involvement in the project. That depends on a number of detailed discussions because people will want to mainly make in kind contributions and they will also not want to make final, you know, firm proposals, if you will, because that is a different kind of involvement and has to go up through channels, in essence, in addition to the detector involvement. They will not want to make those kinds of commitments until they have had an indication of the construction or strong interest in construction in the project, in my opinion.

Those amounts of monies I cannot speak to precisely. I think that they are very substantial, but that until we have a chance to work out the puzzle, if you will, of how their construction contributions would fit in with our construction contributions, we are not in a position to give you a really accurate answer.

We do have groups starting those detailed technical discussions. A group from the URA is going to Japan within the next one to two months to start those types of technical discussions as to how the construction contributions would fit together.

So that is what we see taking place right now.

Mr. MORRISON. Fine. Thank you very much. That is all the questions I have, Madam Chairman.

Mrs. LLOYD. Mr. Schiff.

Mr. SCHIFF. Thank you, Madam Chair.

Dr. Hunter, Congressman Barton made the observation that the SSC's request for next fiscal year would come to about two hours operation of the federal government.

I would like my observation on that to be considered general and not pointed at either Congressman Barton or the SSC. It is just I have noticed even as a freshman that the total number of requests in the federal budget would probably run the federal budget about 35 hours a day, and it seems to be a problem, since we can do a lot in Congress but we can't expand time.

And so I am wondering as both a freshman on this committee and in Congress and as someone who does not have a scientific background—I am, as you know, a lawyer by training and profession—does the Department of Energy offer an opinion as to prioritization? In other words, if the Appropriations Committee comes back and says, now, for energy research we believe that a certain amount of money will be available, does the Department of Energy offer me as a member of this committee some idea of how we think—how you think, rather, the prioritization of those funds should be spent between these various, all worthwhile projects?

Dr. HUNTER. Let me make a couple of comments.

The SSC, which I believe you are alluding to because of how much time is involved in paying for it——

Mr. SCHIFF. Well, but like I say, that is intended to be general. Really, I am not. That is intended to be a generic——

Dr. HUNTER. Well, let me just comment. The SSC has been carried entirely separately from the rest of the Department of Energy budget. In other words, it has not been traded off internally against these other projects, and the OMB has carried it separately. It appeared separately in the President's budget as presented earlier this month.

So that is not—if you will, it has not been traded off in a priority sense against the projects you see before you. What you see you is that we have not funded all the projects or forwarded them—this Administration has not—that are possible this year. We have already gone through our process of evaluation.

I do not know of—I have not yet been through that part of the budget cycle. So I cannot speak to you as to exactly the mechanism by which the Department would be asked to, say, prioritize its choices, if you will, in the rest of the ER budget.

Certainly, there is a mechanism as Congress indicates what it wants to support, you know, as to arriving in the end at some idea on which projects you are actually going to fund, but this Administration has taken the position that in the area of basic research as an overall investment strategy it is an area that warrants a very substantial increase at the moment.

So within those bounds—and we have in fact worked hard within the guidelines we were given to develop the budget before you and the projects that you see—within those bounds we feel that you have received a very good and optimal budget.

So that is what the Administration has forwarded. The exact mechanisms under which you might want to evaluate the different programs I think are something that you would have to discuss with the OMB, if for no other reason than that the SSC itself is carried again separately, since we did not want to compete it with the rest of science.

Mr. SCHIFF. I have one more question, Dr. Hunter.

Carrying the SSC as a separate item outside of the rest of the ER proposed budget, would that be regarded therefore as a special emphasis by the Administration on the SSC? Should I interpret it that way?

Dr. HUNTER. It should be regarded as follows. The project was conceived by the high energy physics community originally in the early 1980's. It became a Presidential initiative. It was held to be of very significant importance in the Reagan and now I believe in the Bush budget. It clearly was a project of sufficient size that for the visibility of it, its impact on the rest of science and questions of that nature, that you wanted to display and carry it separately.

So in that sense, yes, it has received—it is a major initiative. We feel that it would have an enormous impact on science and education in this country, and so it has been carried as a separate item to this date.

Also, it in part reflects the complexity, the recognition early that we needed very substantial international contributions, perhaps of a nonstandard nature, and things of the like have, I believe, led it to be put in a position where it is best evaluated and can best be forwarded.

Mr. SCHIFF. Thank you, Dr. Hunter. Thank you, Madam Chair.

Mrs. LLOYD. Thank you, Mr. Schiff.

Mr. Henry.

Mr. HENRY. I have simply given a written question to Mr. Morrison to submit for me later.

Thank you.

Mrs. LLOYD. Thank you very much.

Dr. Hunter, we will have—there's a lot of questions that I really wanted to ask you and I am sure other members of the committee have questions that they would like to pose to you, also. So we will be—and for all of our witnesses—you can expect questions in writing for the record we will hope that you will respond to as quickly as you can.

Thank you so much for being with us again today. We appreciate your testimony.

Dr. HUNTER. Thank you, ma'am. I enjoyed it.

Mrs. LLOYD. Our next panel includes two Nobel Prize winners. We are very happy to have with us today Dr. Burton Richter, Director of Stanford Linear Accelerator Center, and my friend Dr. Leon Lederman, who is the Director of Fermilab and our 1988 Nobel laureate in physics; Dr. Roy Schwitters, Director of Superconducting Super Collider Laboratory; Professor John Dirk Walecka, Scientific Director, Continuous Electron Beam Accelerator Facility.

To this prestigious panel, I say welcome. Please proceed. Dr. Richter, you are our lead witness.

PANEL 1

STATEMENT OF DR. BURTON RICHTER, DIRECTOR, STANFORD LINEAR ACCELERATOR CENTER

Dr. RICHTER. Madam Chairman, members of the committee, I appreciate the opportunity to appear before you again to testify about the program of the Stanford Linear Accelerator Center.

I ask permission to have the more extended version of my remarks submitted in writing included in the record.

Mrs. LLOYD. Without objection, all of your written remarks will be included in the record in its entirety.

Dr. RICHTER. Thank you.

SLAC is the world's highest energy electron accelerator. Our physics program mainly studies the interactions of electrons and positrons, matter and antimatter. Experiments at electron accelerators like SLAC and proton accelerators like Fermilab provide largely complementary methods of studying the ultimate structure of matter and the forces of nature.

The program of our new SLC accelerator, the SLAC linear collider, a new kind of colliding beam device that allows the study of electron-positron collisions at energies of up to 100 billion electron volts, will be the main focus of my testimony today.

The SLC was designed with two main functions in mind, to prove the feasibility of this new technique as an alternative to larger and more costly storage rings, the previous technique, and to carry out a physics research program in an energy region of great importance.

Our 1989 work began with a new cycle of accelerator development studies together with the program aims at improving the reliability of the facility. The results of this program have been gratifying.

We have proved the viability of the linear collider concept by running beams from LINAC injector through two miles of accelerator and a mile of beam transport and making them collide reliably at the interaction point. We do indeed understand the dynamics of this new and innovative accelerator concept.

Our results to date have convinced the worldwide accelerator community of the promise of linear colliders and R&D programs aimed at future and larger machines are growing in Europe, Japan, and the U.S.S.R.

Accelerator operations began again this calendar year on February 9th after a shutdown to do some installation work, and we expect to begin physics research with the SLC around the middle of March. Our goal is to produce roughly the first 1000 Z-zero particles by the summer of this year. We hope to increase the yield of Z particles by about a factor of 10 in each of the next two fiscal years and for the long term the high rate of particle production coupled with some special features of the SLC that will not be duplicated in other facilities gives prospects of a very exciting long term program.

The President's 1990 budget submission proposes a total operating budget of $122 million for SLAC. Inflation in the Bay Area for a scientific institution like ours is estimated to be 5.5 percent, making the President's budget give a real increase of around $10 million over 1989.

All of this real increase, which is crucial to the exploitation of the new machine, is to go into facility operations and the support of the technology required to develop and improve the machine.

We hope to operate the SLC for 34 weeks in 1990 compared to 29 in 1988 and, in addition, during those 34 weeks to increase the average repetition rate of the accelerator over 1988.

Our equipment budget for 1990 is up by an amount approximately equal to inflation over 1989, and roughly 75 percent of this equipment budget goes to items related to the SLC experimental program.

In conclusion, I would like to summarize. 1989 has seen the resumption of our storage ring program and will see the start of a very important research program with the new SLC.

The 1990 President's budget will allow a large increase in the data collected at the SLC through both increased intensity and operating time and a continuation of important studies with our other machines. We are also building for the future with an R&D program aimed at further development of the linear collider concept.

As before, SLAC's future is intimately connected with the physics of electron-positron collisions, one of the most powerful techniques ever devised for the study of elementary particles and the basic forces of nature.

I hope that the Congress will accept the Administration's funding recommendations, for the opportunities are great not only at SLAC but at Fermilab with the Tevatron-proton collider and at Brookhaven with its unique high intensity, low energy beams.

Thank you.

[The complete prepared statement of Dr. Richter follows.]

TESTIMONY BEFORE THE HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY; ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE

February 23, 1989

Burton Richter
Director, Stanford Linear Accelerator Center

I. INTRODUCTION

Madame Chairman, members of the committee, I appreciate the opportunity to appear before you again to testify about the program of the Stanford Linear Accelerator Center (SLAC). I will discuss our program for FY89 and our hopes for FY90 under the assumption that the President's budget request for next fiscal year is approved.

SLAC is the world's highest energy electron accelerator. Our experimental high energy physics program mainly studies the interaction of electrons and positrons, matter and antimatter, which can annihilate to produce new states of matter and antimatter. Experiments at electron accelerators like SLAC and proton accelerators like Fermilab provide largely complementary methods of studying the ultimate structure of matter and the forces of nature. SLAC is a national facility; its accelerators are used by some 500 scientists who come from more than 50 U.S. universities and laboratories and from many foreign countries. Our high energy physics program is centered on three colliding-beam facilities. The newest of these is the SLAC Linear Collider (SLC), a new kind of colliding-beam device that allows the study of electron-positron processes at collision energies of up to one hundred billion electron volts. The second is the PEP colliding-beam storage ring with collision energies up to thirty billion electron volts. The third is the much older SPEAR storage ring with collision energies of up to seven billion electron volts. In addition to our high energy physics program, we have a smaller nuclear physics program which studies electron-nuclear interactions. Our storage rings also provide X-ray beams from synchrotron radiation which are used by a large and diverse user community for work ranging from the most basic to the most applied.

I now turn to the status of our programs and the implications of the FY90 budget submission.

II. THE SLC

The SLC is a new type of colliding-beam facility for the study of particle physics through electron-positron annihilation. It was designed with two main functions in mind. The first was to prove the feasibility of this new technique as an alternative to the storage-ring technique, because it has, in principle, a more favorable energy scaling law, allowing higher energy machines to be built at considerably less cost. (Indeed, we will have to rely on SLC-like machines if we are to continue to advance the frontier of high-energy electron-positron collisions.) The second was to carry out a physics research program in an energy region of great importance.

Our first run aimed at testing the potential of the facility for elementary particle physics research began in June 1988 and was terminated at the end of July with somewhat disappointing results. During that time the SLC proved difficult to operate with beams of sufficient quality for research use, and the reliability of the facility turned out to be low, primarily but not exclusively because of difficulties with some of the components of the 20-year old linac which were not up to the more stringent requirements of operating in the linear collider mode. Beginning in August of 1988, a new cycle of accelerator development studies was begun, together with a program to improve the reliability of the facility. The results of this program have been gratifying, giving an enormous improvement in the stability of the beam at the end of the linear accelerator, much higher electron and positron beam intensities at the collision point, improved operating procedures that considerably speed the set-up of the beams, dramatic reductions in background events in the detector, and a sharp reduction in unplanned downtime. Operations were interrupted in the middle of December to allow installation of further improved systems that could not be installed while the facility was in operation.

The work on the accelerator during this period has proved the viability of the linear collider concept. Beams from the linac injector can be brought through two miles of accelerator and more than a mile of beam transport systems and be made reliably to collide at the interaction point, thus proving that we do indeed understand the dynamics of this new and innovative accelerator concept. Our results to date have convinced the worldwide accelerator community of the promise of linear colliders, and R&D programs aimed at future and larger linear colliders are growing in Europe, Japan and the U.S.S.R.

Accelerator operations began again on February 9, 1989. It will take us about five weeks to commission the new systems that have been installed during the recent down time, and we expect to begin physics research with the SLC around the middle of March. Our goal is to produce roughly the first thousand Z^0 particles by the summer of this year. Although this is but a small fraction of the rate we hope eventually to achieve, it should be sufficient to address such important issues as the precise value of the Z^0 mass and the width of the Z^0 resonance (which constrains the number of as of yet undiscovered generations of elementary constituents), and also to determine whether or not certain classes of new particles that might be produced in Z^0 decay are indeed so produced. The Mark II detector is on the beam line, is well tested and ready to take data, and we believe that the machine will produce that data.

We hope to be able to increase the yield of Z particles about a factor of ten in each of the next two fiscal years. For the long term, the high rate of Z production, coupled with two special features of the SLC that we believe cannot be duplicated on other facilities, give prospects of an exciting long-term physics program. The two special features are electron-beam polarization and extremely small beam size.

Longitudinally polarized electron beams were produced and used at SLAC a decade ago. A new polarized source is being developed that matches the special requirements of the SLC injector, and the first prototype of this polarized source is now installed on the machine and awaiting testing. With polarized beams, certain classes of experiments can be done which are impractical without polarization, and we expect to have these beams available for the experimenter within the next two years.

The extremely small size of the SLC beam at the collision point (a factor of about 1000 smaller in area than in current storage rings) allows the use of a certain class of so-called vertex detectors that are extremely difficult to implement with the larger beams characteristic of storage rings. These vertex detectors allow particle identification through the observation of decays that occur very close to the production point. The particle identification through decay, coupled with polarized beams, makes an extremely powerful technique for dissecting in detail what happens in the electron-positron annihilation reactions. These details are often crucial for progress toward new discoveries. The SLD detector, scheduled for completion next year, has all of the capabilities necessary to exploit these opportunities.

We expect to have a world-class research program running on the SLC at the very least through the mid-1990s.

III. THE STORAGE RING PROGRAMS

The long drought of storage-ring data ended at the beginning of this fiscal year. The higher energy storage ring, PEP, began operating with an improved focusing system near the main collision point that considerably increased the luminosity (related to the rate at which data is produced) over what could be obtained previously. Peak luminosities were up by a factor of three, and we have not yet reached the limiting luminosity in this facility. The main detector on the PEP ring, the so-called "TPC," is also improved over its previous configuration, and we expect this unique facility to produce large amounts of new data over the next several years. A new kind of experiment has been approved that involves the collision of the circulating beam in the storage ring with gas-jet targets, which allows certain unique kinds of nuclear physics experiments to be done that are complementary to those that can be performed at CEBAF. In addition, the PEP storage ring supplies the brightest beams of synchrotron X-rays that are obtainable now in the world, and these are beginning to be used for experiments as well as to assist in development work for the next generation of U.S., European and Japanese six to eight GeV synchrotron light facilities.

SPEAR also began taking data in the same configuration that had been used before. Our present plans are to complete the high energy physics experiment that is now running on the machine (one to two more years) and then to make SPEAR available full-time for dedicated synchrotron radiation use. The reason for this decision is the beginning of operation of a storage ring at the Institute of High Energy Physics in Beijing, Peoples' Republic of China, which covers the most interesting part of the SPEAR energy region and is expected to have a luminosity a factor of five greater than can be obtained at SPEAR. We are happy to have been able to assist our Chinese colleagues in the design of this ring and its detector facility. The turn-on of this machine is proceeding very well, and if all goes as expected in Beijing, SPEAR will not be a competitive high energy physics facility in a few years' time. The resources used to operate it would be better devoted to other areas of research at SLAC.

IV. ADVANCED ACCELERATOR R&D

An important part of SLAC's mission is the development of new accelerator technology that will allow higher energy and more cost-effective accelerators to be built in the future. While a significant part of this program is aimed at improving the performance of our existing machines, the main focus at the moment is on advanced linear colliders. While the technology of the SLC could be applied to building higher energy machines, the resulting accelerator would be more expensive and energy inefficient than is desirable. Our work currently emphasizes studies of advanced RF power sources (in collaboration with Lawrence Berkeley Laboratory and Lawrence Livermore National Laboratory), advanced accelerator structures, and theoretical studies of beam dynamics issues. As I mentioned earlier, Japan, Europe and the U.S.S.R. are also interested in high energy advanced linear colliders, and we are coordinating our work and cooperating in certain projects. In particular, we have been designing an advanced beamline that will allow the testing of the new focusing concepts required to realize higher energy machines. Japan and the U.S.S.R. have agreed to participate, and we are continuing our discussions with the Europeans. It is still much too early for anyone to be able to make a realistic design for a very large linear collider facility, but with international collaboration in the R&D process, all the regions involved hope that we can collectively proceed faster than we could if it were necessary for each to "go it alone."

V. BUDGET ISSUES

The President's FY90 budget submission proposes a total operating budget of $122 million for SLAC. Inflation in the Bay Area for a scientific institution like ours is estimated to be 5.5%, making the President's budget give a real increase of about $10 million over FY89. All of this real increase, which is crucial to the exploitation of the new machine, is to go into facility operations and high energy technology. Facility operations costs at SLAC are dominated by SLC costs, for this is the accelerator that consumes most of the power and uses the full linear accelerator. We hope to operate the SLC for 34 weeks in FY90, compared to the scheduled 29 in FY88. In addition, we will increase the average repetition rate of the accelerator in FY90. Roughly $7.0 million of the net real increase goes to accelerator operations, of which $3.0 million is for increased power and $4.0 million is for increased maintenance and consumables.

The remaining $3.0 million of the real increase goes to accelerator technology, split roughly 50/50 between R&D aimed at our existing machines and R&D on future linear colliders.

The equipment budget for FY90 is up by an amount approximately equal to inflation over FY89. Roughly 75% of the equipment budget goes to items related to the SLC machine, including completion of the SLD detector, a new computer for data analysis, and completion of the polarized-beam project. The remaining 25% of the equipment budget is distributed over many programs in the laboratory, including the research programs at the storage rings.

I also note that the President's budget submission requests a 27% increase in accelerator improvement funds, and a 21% increase in general plant project funds. I strongly support both of these requests, for these categories are where all of the laboratories get their funds for upgrades and modification of the conventional plant and existing accelerators. Considering the enormous capital investment in accelerators and buildings at SLAC, Brookhaven and Fermilab, this is a modest amount indeed for such purposes.

VI. CONCLUSION

To summarize, FY89 has seen the resumption of our storage ring program and will see the start of a very important research program with the new SLC. The FY90 President's budget will allow a large increase in the data collected at the SLC, through both increased intensity and operating time, and a continuation of important studies with our other machines. We are also building for the future with an R&D program aimed at further development of the linear collider concept. As before, SLAC's future is intimately connected with the physics of electron-positron collisions — one of the most powerful techniques ever devised for the study of the elementary particle and basic forces of nature. I hope that the Congress will accept the Administration's funding recommendation, for the opportunities are great, not only at SLAC, but at Fermilab with the Tevatron proton collider and at Brookhaven with its unique high-intensity, low energy beams.

Mrs. **Lloyd**. Thank you very much, Dr. Richter.

I would like to at this time recognize Mr. Fawell.

Mr. **Fawell**. Thank you, Madam Chairman.

I simply wanted to have the privilege of reintroducing Dr. Lederman, who is appearing here, of course, as the Lab Director at Fermi, and I am sad to say that this is the last time, I gather, that Dr. Lederman will be here in that capacity. He—and we feel sadly about this back in our district—is leaving Fermi, though we rejoice with him. He is going on to another challenge at the University of Chicago in some professorial capacity, basically I think aimed at aiding in the education of young people, as I understand it, in science.

So I simply wanted this privilege, Leon, to introduce you and to thank you personally and I think on behalf of the committee for all the fine things you have done. You have combined with Dr. Robert Wilson to create certainly the essence of high energy physics in that Tevatron that you have out there, and all of the fine things you have done for our area we much appreciate—the Illinois Math and Science Academy and just so many other things.

We shall miss you very, very much. So godspeed, and again I am just happy to have the chance of introducing you at this time.

Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you.

Mr. Schiff.

Mr. **Schiff**. Madam Chair, I would like to take just one minute, though it deserves more, to observe that I attended with you and other members of the subcommittee a field hearing in the Chicago area. We visited the Argonne Lab and Fermilab, and I just wanted to thank Dr. Lederman for his personal courtesy and also his staff for sitting down with me for some time that evening and just doing their best to explain high energy physics to an attorney as quickly as they could.

Thank you, Dr. Lederman.

Mrs. **Lloyd**. I would also like to express my appreciation to Dr. Schriesheim and Dr. Lederman for their hospitality when we did have field hearings in the Chicago area, and we certainly learned a lot both at Fermi and at Argonne.

With that introduction, please proceed. You can't go wrong with that.

Dr. **Lederman**. Do I have to testify? [Laughter.]

Mrs. **Lloyd**. We have put a halo around your head as you are going out.

STATEMENT OF DR. LEON M. LEDERMAN, DIRECTOR, FERMI NATIONAL ACCELERATOR LABORATORY

Dr. **Lederman**. It is an honor to testify before this committee and alongside of my distinguished colleague from California, Professor Burton Richter.

Although this is a panel on high energy physics, I would like to begin with my strongly held opinion that this nation will flourish or not depending on its recognition that science and associated technology is the single most essential ingredient in the large menu of activities that a nation inevitably has.

A recent President doubled the military budget to its present $300 billion without obviously destroying the nation. One can imagine that the United States could double the basic research budget of $10 billion as perhaps the best investment that can be made in our future.

I might remark as an expert on economics and all those things that no other investment offers the kinds of returns of 10 to 1 or 100 to 1 or even a million to one that science and associated technology can offer.

High energy physics is an essential element in this equation, and that leads me of course to my subject, Fermilab, where we do high energy physics.

In the years 1978 to 1986 your committee helped us to invest over $500 million in the Tevatron program, the superconducting accelerator, its collider and fixed target applications, all the front line R&D that we did, and the equipment needed to do the research, and now it all works. It works better than even we thought it would. Today, at an energy of 1.8 trillion electron volts, Fermi's collider produces over twice as many collisions per second than our design specifications. We lead the world in energy and in accumulated collisions observed.

As I speak here now, young scientists are monitoring the performance of the CDF collider detector, watching computer playbacks of protons colliding head-on with antiprotons at three times the energy of our European colleagues and competitors at CERN.

The excitement and potentiality for discovery is palpable. What was an exotic European discovery in 1984, the W's are now seen by the many thousands and the companion Z particles by the many hundreds. With this superb facility, world science is advanced and the United States is in the lead.

It is very likely that we can hold on to this lead until SSC comes on in spite of an impressive new European machines like LHC, UNK, and the HERA machine, and that is briefly outlined in my written contributions.

So what are the problems?

I think there is a general consensus, which the Congress seemed to share, judging from the past year's budgets, that a vigorous program of high energy physics should be maintained during SSC construction, and I most emphatically hope that Congress goes forward with the SSC in fiscal year 1990.

The fiscal year 1990 budget request does seem to satisfy these goals. In the case of Fermilab, the $500 million investment must be exploited and not allowed to atrophy. To assure this we need a decent operating budget and a continuous effort to improve our facilities. Both are contained in the President's budget request for fiscal year 1990.

In commenting on the fiscal year 1990 budget, I am faced with an anguishing dilemma.

No sane physicist can complain about the DOE treatment of high energy physics in fiscal 1990. The SSC is proposed for construction, and non-SSC high energy physics is in for a respectable increase.

In view of the deficit crisis, this is indeed very favored treatment, but let me convey our dilemma.

Fermilab has come through a tremendous intellectual and backbreaking ordeal. A judgment as to what science to pursue, what machines to build, how to build up were not obvious, but these are now conceded to have been correct.

We now have the most powerful accelerator ever built by the end of fiscal 1990. We will have two complementary detectors and a splendid array of fixed target experiments being used by scientists from some 70 U.S. universities and 17 foreign countries.

The potential of the discovery will not be rivaled for perhaps a decade.

In spite of all of these good things, the esprit of the laboratory has been badly shaken by the SSC site decision. We must put this behind us and get on with our great tasks.

However, this depends on two elements, the operating budget and the increments for continuous improvement of the Tevatron, of which the fiscal 1990 LINAC upgrade is the first element.

If, as has happened in several previous years and is certainly a possibility this year, the President's budget request for high energy physics is reduced by the Congress, this unique and powerful research engine will sputter and cough, esprit will sink further, and we will have snatched defeat from the jaws of victory.

Frankly, ladies and gentlemen of the subcommittee, I am uncertain about the future and therefore very concerned that we may fail to exploit this superb scientific instrument, and I therefore beg your considerable influence in assuring that the fiscal year 1990 budget request be fully allocated.

Finally, since this is my last opportunity to testify before this committee as Fermi Director, I would like to thank you all for your past support and urge all of you who have not visited Fermilab to visit and see not only the great science in the doing, but also the very considerable number of outreach activities about which we are very proud.

Thank you.

[The complete prepared statement of Dr. Lederman follows:]

Testimony of Leon M. Lederman
Fermi National Accelerator Laboratory
Committee on Science, Space and Technology
Subcommittee on Energy Research and Development
23-FEB-89

INTRODUCTION

Although this panel is on High Energy Physics (HEP) I must introduce it by commenting that in my biased opinion, this nation will flourish or not depending on its recognition that science and increasingly related technology is the single most essential ingredient in solving many problems facing this nation, ranging from economic competitiveness to critical environment problems, to the forthcoming revival of the energy crises, and depletion of essential materials. I would hope that, just as President Reagan succeeded in doubling our 160 billion dollar defense budget in his eight years, so some wise leader is going to determine to double the $10 billion research budget as the best possible investment the nation can make in the future. I hope this is not too late. Of course there are necessary ancillary activities such as science education, such as technology transfer, such as a renewed interest on the part of industry in long range investments and so on.

But I digress. HEP contributes to all of this in an essential way because it shores up the cultural end of the structure we call science and plays a crucial role in science education. And science/technology needs this pillar or, sooner or later, the entire structure will topple. We, on this panel, do HEP out of passion for understanding of the most fundamental question: ''How does the universe work?'' On behalf of my colleagues, I promise that as soon as we find the answer to this question, we'll quit and stop spending the public's money.

BRIEF HISTORY

Now let me give you a status report on Fermilab, its successes and its problems. First, a brief recapitulation. The Lab was funded as a 200 GeV machine with 8 beam lines at a cost of $250M (1968). In 1972, the machine came on at 200 GeV, in 1973 it went to 300 GeV, in 1974 to 400 GeV with 14 beam lines and in that year, some $6.5M was returned to the U.S. Treasury from the initial appropriation. Several million dollars still left over were used to start R&D on an advanced technology accelerator, using superconductivity.

In 1979, Congress approved the Energy Saver/Doubler, the first superconducting synchrotron which worked in 1983. In the next several years, Fermilab constructed the proton-antiproton collider (TeV I) and the experimental area complex (TeV II) as well as a variety of particle detectors, in collaboration with scientists from some 70 U.S. universities and physicists from some 17 foreign countries.

In the years 1978-1986, we invested, in these 9 years, over $500 million in the TEVATRON program. This includes R&D, equipment and construction funds. It all worked! It worked much better than even we expected. Today, at an energy of 1.8 TeV, Fermilab has a collider that produces over twice as many collisions/sec as was in the design specifications. We lead the world in energy and in integrated collision rate. As I speak here, back at Fermilab young scientists are monitoring the control room of the ''CDF'' detector, watching the head-on collisions of protons and antiprotons at three times the energy of our nearest competitor at CERN. The excitement and possibility for discovery are palpable. The world's collection of recently exotic Z^0 and W particles, yesterday's Nobel prize particles (actually 1985) are now collected by the hundreds and thousands. With this superb facility, world science is advanced and the U.S. is in the lead.

It is very likely that this leadership can last until 1998 or even longer, before SSC or a European version (LHC) comes on the air. Our fixed target program serves about 50% of the U.S. community and provides a rich variety of essential experimental research at more modest energies. This too is a world leader.

STATUS, CHALLENGES, PROBLEMS

I have appended a few charts (I and II) to illustrate how well the Fermilab accelerators are working. Scientific results are also beginning to emerge out of the entrails of the computers which are so essential to the analysis of modern particle physics data. One of my charts (III) illustrates the power of the Tevatron compared to previous, existing and even soon to be operating machines. We are proud that the Tevatron has become the technical model for machines under construction in West Germany (HERA), in the Soviet Union (UNK) at CERN (LHC) and our own SSC.

So what are the challenges and problems?

The challenges are really the following: There is a general consensus, concurred on by the Congress, if I judge from its actions in recent years, that a vigorous program of high energy physics must be maintained during SSC construction. This assumes, and I most emphatically hope this is correct, that the Congress lets SSC go forward in FY90. Clearly in the case of Fermilab, the total investment of $500 million over the past 9 years must be exploited and not abandoned. Otherwise questions will inevitably be raised about the commitment to exploit the $5 billion investment in the SSC. To Keep the U.S. at the frontier one needs a reasonable operating budget and a continuous effort at upgrading the facilities. This makes not only good science sense, it is congruent to the need to shore up the base of our science and technology upon which the success of the physics exploitation of the SSC must rest. I include as Appendix I an outline of the Fermilab Upgrade plan as refined from my testimony of last year.

The problem is that our budgets over the past four years (see Chart IV), i.e. those items which address the issue of exploitation, have barely kept up with inflation. The Lab's success has been largely a product of enormous human effort and ingenuity in the use of scarce resources.

THE FY 90 PBR

In commenting on the FY90 budget, the Fermilab Director is faced with an anguishing dilemma. On the one hand no one in his right mind can complain about the DOE treatment of HEP in this FY90 PBR. The SSC is proposed for construction and non-SSC HEP is in for a respectable increase. In view of the extreme sensitivity of everyone to the overall fiscal austerity, how dare anyone complain? But let me convey the dilemma. We at Fermilab, have come through a tremendous intellectual and back-breaking effort. Our judgement on what science to pursue, on what machines to build, on what geniuses to entrust with these many tasks, all of these are generally conceded to have been correct, even inspired, if I say so myself. We now have the most powerful particle accelerator ever built. By the end of FY90, it will have been fully instrumented with two complementary collider detectors and a splendid array of fixed target experiments. Physics data has been pouring out. The potential for important discovery cannot be rivalled. The ability to address the details of our knowledge base via the fixed target program is also unique although here we may be overtaken by the USSR in H 1995 or so. However all of this depends on two elements: A reasonable operating budget as is in fact given in the FY90 PBR and the increments for continuous improvements, of which the FY90 LINAC Upgrade is the first element. If, as has happened in several previous years, the HEP budget is reduced by Congress and if the DOE's of cuts to Fermilab follows the pattern of previous years, this unique and powerful engine will sputter and cough and we will have snatched defeat from the jaws of victory. Frankly, ladies and gentlemen of the Subcommittee, I am terrified that we may fail to exploit this superb scientific instrument and I beg your help in assuring that the FY90 Budget Request be fully allocated.

It remains only to try to convince you that upgrading the Tevatron is essential to the exploitation. In the simplest terms it comes to this: In the present collider run, we will have collected data corresponding to 50 billion collisions (5 pb-1) of protons against antiprotons. The next run, with improvements already in the process, should add a very significant 200 billion collisions (20 pb-1). If we do not continue this progression, the following year would again yield 200 billion collisions and the value of the data would improve by the famous ''square-root'' law i.e. only by 40%. It then becomes cost ineffective to continue the investment of public funds and human effort to add a third increment of 200 to the accumulated 450 billion collisions.

Alternatively, with the complete upgrade, the collision yield can eventually rise to 10,000 billion collisions (1000 pb-1). This yield permits an exploration of fundamental physics far beyond anything presently contemplated until we have a fully operational SSC. If this all takes place by 1995, there is a period of about 5 years to accumulate and digest the data to advance the science and to thereby accommodate and steer the SSC physics program accordingly. The FY '90 PBR looks good relative to the past 4 years but we have been here before and have seen reasonable increases whittled away by Congressional cuts with, in our highly subjective view, inadequately sound apportionment, by the DOE, of these cuts.

FY 90 GOALS

Our goals for FY90 are the following: In the fall of 1989 we will turn back to the fixed target mode from the present collider run. We will provide some 16 experiments with beam, serving about 800 physicists including 287 graduate students, a veritable Fort Knox of intellectual treasure! Each experiment is, in this physics-for-the-people mode, composed of from 10-60 collaborators (small groups!). We will also be supplying several test beams where R&D on SSC detectors are being carried out. [Collaboration with SSC is in fact extensive, ranging from beam orbit studies using the TEVATRON, to R&D on SSC accelerator magnets.] During this time we will be completing the DZERO Collider detector in order to have it installed, if at all possible, for the next collider run.

Late in the year we will turn back to the Collider mode where we hope to begin the implementation of the DZERO detector. The funds allocated in the PBR should allow us to operate for about 9 months. Its weakness is that there will not be enough in the R&D allocation to advance the performance of the TEVATRON at the pace which our scientific potential demands. Here we are short about $10 million. Finally, we expect, in FY90, to begin the Phase I Linac upgrade although at a slower pace than originally hoped.

However, if there are cuts or, as happens from time to time, DOE taxes, the Laboratory is too stretched to carry out its mission of keeping U.S. HEP in the world class, in the face of W. Germany's HERA, CERN's LEP and the USSR's UNK. We look especially longingly at the Linac UPGRADE, line item, for which $4.7 million was requested in the PBR. The Linac Upgrade is the key to the next ten years of Fermilab operations and we are very pleased to have it in the budget.

FINAL REMARKS

I close with some philosophical comments. This will be my last testimony as Fermilab Director. In Chart V I took the liberty of listing major initiatives over the past decade of my watch at Fermilab. Ten years ago, I succeeded Robert R. Wilson, the founding director. Between us, we have created a unique institution. There is no other national laboratory like it. There are no models like Fermilab with its technical success but also in its unique outreach programs. Many members of both houses of Congress have visited Fermilab over the past several years. Those of you who have visited know about our many educational programs that attend to third graders and continue through junior and senior high school and to the science teachers. You know about our technology transfer, via Fermilab's Industrial Affiliates and, most recently, the Loma Linda medical accelerator. You know about our involvement with developing country scientists in Central and South America, you know about our ecological research, prairie restoration wildlife preserve, our child care center, and other outreach activities indicated in the chart.

I think you will agree that all of this is not bad for a laboratory whose primary mission is to answer the question, How does the universe work?

Appendix I: Tevatron Upgrade

The Fermilab future is set out in an upgrade plan which has been divided into three phases, the first two of which have been presented to DOE. Phase I is in the FY90 budget. We'd like Phase II in the FY91 budget. It requires about 10% of the Tevatron investment as an increment to the Fermilab annual budget. Its virtues can be summarized:

(1) By increasing the collision rate, the power of the Tevatron to explore the unknown territory beyond our present understanding (as expressed by the Standard Model) is very greatly extended. These are the foothills and badlands before the giant peak the SSC will attempt to scale by the end of the 1990's. All attempts to achieve a unified theory predict the existence of particles and phenomena that will be tested by an upgraded Tevatron.

(2) An examination of the world-wide activity indicates that this program will keep U.S. in the lead in high energy until SSC and/or the European LHC comes on in the late 1990's.

(3) Fermilab can continue to produce the bulk of Ph.D.'s and trained post-docs that will be essential to a healthy science. Such young investigators must engage in publishable physics and cannot commit to SSC until at least minus 2 years prior to completion i.e. 1996-1998.

(4) In the sensible world of SSC under construction and an otherwise flat HEP program I believe we can afford the Tevatron Upgrade at the level of about $50M/year out of a total annual budget of $600M (non-SSC). This expenditure is required through about 1995 and then we can afford the beginning of a post-SSC electron-type accelerator should the science and the technology so dictate.

(5) Finally we note that the Fermilab Upgrade is essentially a replacement of older components and therefore does not have operating budget implications.

CHART I

Tevatron Collider Operation

Integrated Luminosity at 900 GeV

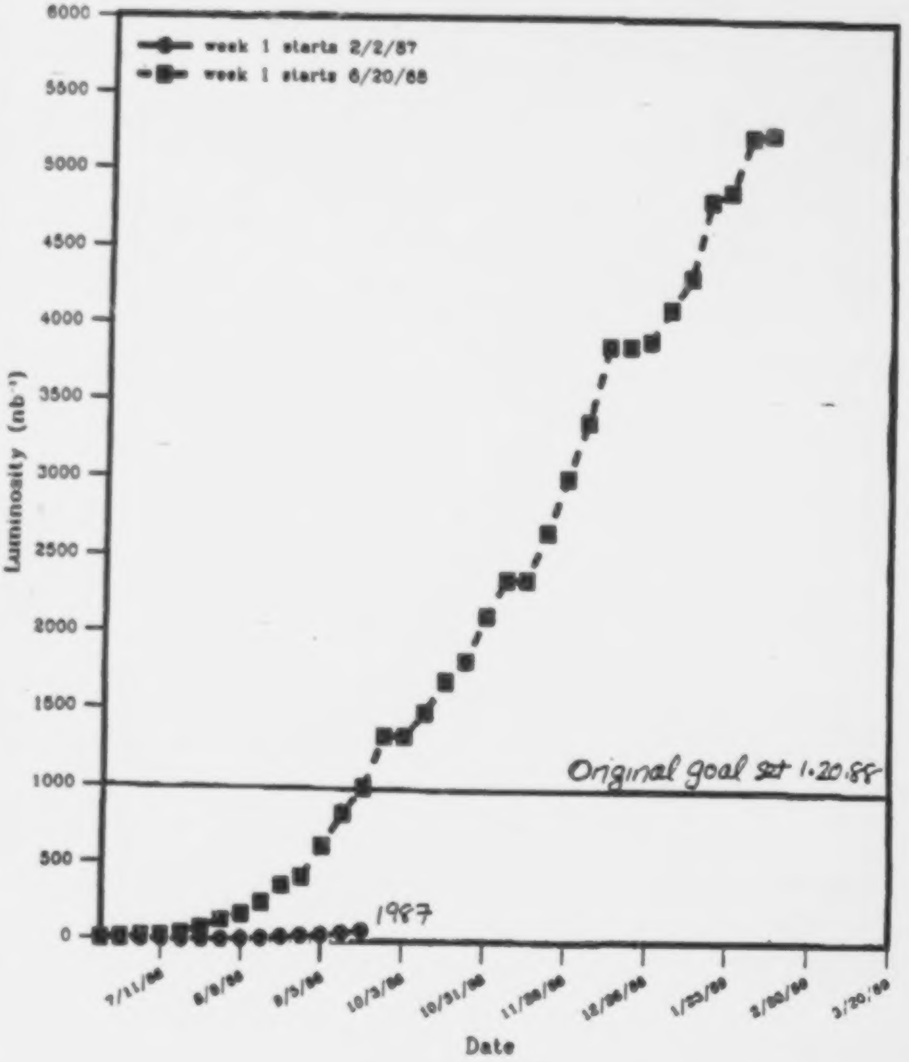


CHART II

Typical Before Tevatron and After Tevatron Experiments.
1

E-715	The Beta Decay of the Sigma Hyperon	
	1984, E-715 The previous world collection	50,000 events 400 events
E-621	CP-Violating Parameters Eta + - 0	
	1985, E-621 A Total of eight earlier experiments	3×10^6 events 12000 events
E-744	Neutrino Scattering	
	1985, events with $E_\nu > 300 GeV$ Previous world total	300,000 0
E-605	Dileptons Produced by Protons	
	1985, E-605 with $\Delta p/p = 0.2\%$ Previous (E-288) with $\Delta p/p = 2\%$	20,000 Υ's 5,000 Υ's
E-731	CP-Violating Parameter ϵ'/ϵ	
	1987, E-731 $K_L \to 2\pi^0$ Predecessor E-617	300,000 events 3,000 events
E-756	Tevatron Hyperon Physics	
	1987, E-756 $\Omega^- \to \Lambda K^-$ Previous world total	100,000 events 16,000 events
E-691	Photoproduction of Charm	
	Total number of charmed decays fully reconstructed World's collection from all e^+e^- machines	10,000 events $\sim$ 5,000 events

CHART III

NEW AND PROPOSED ACCELERATORS

		Energy	Effective Mass Reach
Fermilab Collider (proton-antiproton)	2000 GeV	(1988) (1994)	300 GeV now 600 GeV with Upgrade
CERN's LEP (+SLC)	100 GeV	(1989)	100 GeV
LEP II (electron-positron)	200 GeV	(1993)	200 GeV
W. Germany, HERA (proton-electron	1000 GeV p x 30 GeV/c	(1999)	~ 150 GeV
USSR, UNK (proton-proton)	3000 GeV 6000 GeV	(1994) (1997-9?)	~ 77 GeV ~ 600 GeV initially
U.S. SSC	40,000 GeV	(1998?)	3000 GeV
W. Europe LHC (proton-proton)	18,000 GeV	(1998?)	1500 GeV

CHART IV

FERMILAB BUDGETS

	FY 85	FY 86	FY 87	FY 88	FY 89	AVG Change per yr	PBR'90	Percent Change
Operations	118.3	112.2	126.9	137.1*	146.2		162.8	
Equipment	27.5	31.2	27.9	27.3	28.7		30.6	
Sum	145.8	143.4	154.8	164.4*	174.9	4.4%	193.4?	10.6%
Plant	41.6	19.3	15.8	20.1	13.1		15.8	
Total	187.4	162.7	170.6	184.5*	188.0	0%	209.2?	11.3%

*An additional $2.7M was costed in FY 88, reducing GSO

CHART V

LML
Revised-22-FEB-89

FERMILAB: 1978-1989

I. Construction Projects (Major)
   - A. Energy Saver
   - B. TeV I (Antiproton complex)
   - C. TeV II (Fixed-Target complex)
   - D. The Tevatron Fixed Target Program
   - E. Colliding Detector Facility (CDF)
   - F. D-Zero Colliding Detector (D0)
   - G. Computer Center
   - H. Advanced Computer Program (ACP)
   - I. The Tevatron Upgrade Concept

II. Intellectual Environment
   - A. Astrophysics Group
   - B. Bj (James D. Bjorken, senior theorist)
   - C. Director's Reviews
   - D. Director's Coffee Hour
   - E. Distinguished Lecture Series
   - F. History of Particle Physics Symposia
   - G. SAG and Jr. SAG

III. Education
   - A. Saturday Morning Physics
   - B. Friends of Fermilab (and its many science education programs)
   - C. Illinois Math and Science Academy
   - D. Ph.D. Program in Accelerator Science
   - E. Wilson Fellowships
   - F. Video News of the Week
   - G. Minority URA Fellowships
   - H. Visitors and Education Center

IV. Fermilab Industrial Affiliates Group

V. Annual Reports

VI. Pan American Activities

VII. Users Center and Chez Leon

VIII. Day Care Center

IX. Cancer Treatment and the Loma Linda Accelerator

Mrs. LLOYD. Thank you, Dr. Lederman. We do look forward to you being back before this committee in other capacities as well.

Dr. Schwitters.

STATEMENT OF DR. ROY F. SCHWITTERS, DIRECTOR, SUPERCONDUCTING SUPER COLLIDER LABORATORY

Dr. SCHWITTERS. Madam Chairman, members of the subcommittee, I want to thank you for this first opportunity to be before you on behalf of the many U.S. high energy physicists who are deeply committed to building the superconducting super collider as the next instrument to further this exciting and historically important area of science.

The scientific case for the super collider continues to strengthen as questions about our present understanding grow and as experience with today's experimental tools accumulates.

Today I would like to present my personal views as one just entering this tremendous project. In my written testimony a somewhat more detailed snapshot of the SSC project has been prepared with the aid of experts from the central design group and with new staff members of the SSC Laboratory.

Recently, two major milestones for the SSC were passed. Ellis County, Texas was selected to be the site, and the university and industry consortium headed by Universities Research Association was chosen as the management and operations contractor. Thus, we now know the performers who will actually carry out this project.

In addition, these two events involve substantive review of the basic budget assumptions underlying the SSC. In both cases no evidence has turned up indicating a substantial increase in the basic cost estimate that was prepared by the central design group.

With regard to site selection, I was a member of the national academy panel that reviewed all of the state proposals and recommended the best qualified list to DOE. In reading every proposal, I was most impressed by their consistently high quality and I was deeply moved by the spirit, genuine interest and boldness that many states brought to this project. Any one of the best qualified sites would have provided an excellent home for the SSC.

Texas was picked by DOE, and it offers the country an outstanding site.

As Director, however, I am committed to building a national laboratory in Texas where the scientific, educational, technological, and cultural benefits are available to all.

The selection of URA as SSC M&O contractor means that the highly successful tradition of academic leadership in our national high energy laboratories will continue.

However, to help maintain a viable U.S. high energy program during SSC construction to allow our scientists to focus on the demanding physics challenges of the SSC and to draw on outside experience with large technical projects, the URA SSC team is establishing new working relationships with industry.

For example, URA has teamed with two national companies, EG&G and Sverdrup, in the management of the laboratory. Sixteen industrial concerns have joined the magnet industrialization program.

Just two weeks ago in New Orleans there met the first international symposium, international industrial symposium on the super collider. I must say it was a smashing success, with over 700 participants from industry, the scientific community, and Ellis County.

We seek industrial involvement wherever possible to further the SSC project.

Many challenges face our new SSC management team, but we also have an opportunity now to take a fresh look at the project. The Central Design Group has provided us with a strong base from which to work, but over the next year we will be questioning everything as we move to a definitive design. We will not make changes without compelling reasons, and we are committed to use our best efforts to keep the construction budget within present cost estimates.

Some of our main tasks for the next year or two are as follows:

First, recruiting a first-rate staff.

Second, preparing a site specific design and cost estimate.

Third, pursuing aggressively to completion the necessary R&D programs for accelerator systems.

The major effort here will continue to be the magnet program, which has successfully produced and tested two full-scale and several shorter prototype magnets. The most recent full-scale, full length prototype, however, did not hold full current and we must understand completely the reason for this. I am appointing an expert review panel to fully examine the SSC R&D magnet program.

Fourth, we have to begin initiating the scientific program by continuing to foster a nationwide detector R&D program and establishing guidelines and schedules to begin detector selection and construction.

As you know, this will involve the major participation of universities across the country.

Fifth, on our agenda is to work with the government to secure nonfederal sources of support for the SSC.

Sixth, which is also very important, is to establish a base of operations near the site as soon as we can.

Of vital importance to all these tasks is the need for a commitment now by the U.S. Government that the SSC will go forward. We are pleased with the President's DOE budget request for fiscal year 1990 funding. Congress' adoption of this funding level will provide the commitment required to initiate this project with the vitality needed to complete it in a timely and cost effective way.

I am honored to have been selected to direct the SSC. It is a unique privilege to have the opportunity to create from the lovely countryside of Ellis County a great international laboratory where the world's best scientists and their students will flock to work on the greatest scientific instrument of our time.

I look forward to working with you, with all of you, in the future of this project, and I will do everything I can to keep the subcommittee fully informed on our activities.

Thank you for your consideration. I shall be happy to answer any questions.

[The complete prepared statement of Dr. Schwitters follows:]

SSC Status

Prepared testimony of Prof. Roy Schwitters, Director

Superconducting Super Collider

before

Subcommittee on Energy, Research, and Development

Committee on Science, Space, and Technology

U.S. House of Representatives

February 23, 1989

Introduction

Madame Chairperson, Members of the Committee, it is a real pleasure to appear before you today to testify about the Superconducting Super Collider. As the new Director of the SSC Laboratory, I represent the consensus of the whole U.S. high-energy physics community who have, for several years now, supported the idea of a speedy construction of this scientific instrument as the number one priority of the U.S. particle physics program.

These are exciting times for high-energy physics. We feel that our ability to achieve energy levels that will lie in the domain of the SSC will allow us to answer some of the questions that mankind has investigated for several millenia. In my testimony, I hope to indicate some of the scientific motivations for this instrument, describe the progress that has been achieved on the SSC during the last few years, and outline to you our plans for the future.

Particle Physics Today

The ultimate secrets of matter and energy are to be found in the world of elementary particles. These particles make up all matter, and they obey laws that, as far as we know, apply at any time and place in the universe. The goal of particle physics is to map out this world and discover the rules that govern its behavior. This knowledge has far-reaching consequences for our understanding of what the universe is and how it came to be.

Ours is hardly the first time in history that physicists have believed themselves close to an enduring understanding of the laws of nature. What, then, are the grounds for believing that, whether or not a grand synthesis of natural law is near at hand, important progress is under way? Over the past two decades, the age-old struggle to describe and comprehend the nature of matter has been rewarded by a radically new and simple picture of nature on the most basic level. A host of new experimental results, made accessible by a new generation of particle accelerators, and the accompanying rapid convergence of theoretical ideas have brought to the subject a new coherence and have raised new aspirations. The new insights not only provide a framework for describing and understanding the world around us, but also elucidate the first instants after the creation of the universe.

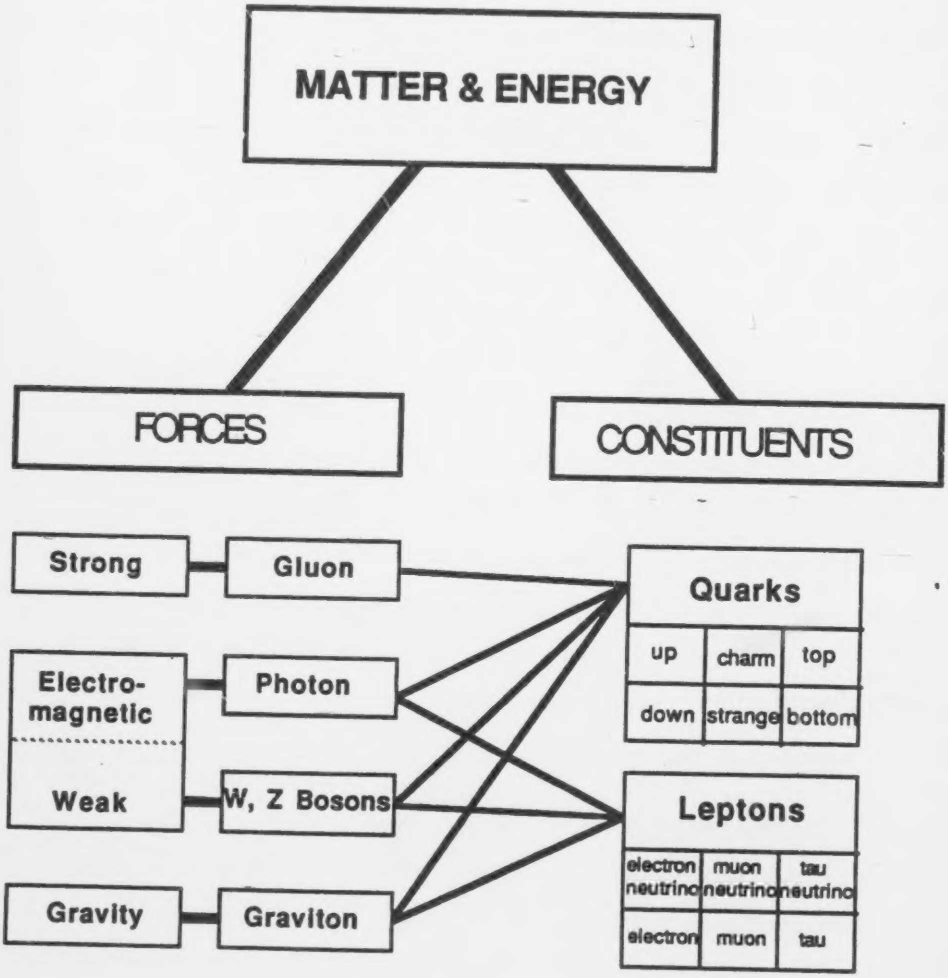
Our present picture of the composition of matter has two elements: a set of fundamental constituents and a small number of fundamental forces, or interactions. These are represented in the accompanying figure. The fundamental constituents are called *leptons* and *quarks*. A class of mathematical theories called *gauge theories* provides a common framework for discussing all the fundamental interactions and therefore gives us the hope of seeing connections between these interactions.

Some Open Questions

The advances of the past decade have brought us tantalizingly close to a profound new conception of the basic constituents of matter and their interactions. The simpler and more comprehensive understanding we have gained organizes current knowledge and locates the horizon of particle physics at energies of trillions of electron volts and the horizon of cosmology at about a millionth of a billionth of a second after the moment of the creation of the universe as we know it as physicists. Even though lower energies may provide hints of new phenomena, exploration of these uncharted territories lying beyond the horizons of present knowledge is bound to yield new insights into the unknown.

The understanding that we have gained during the past year into the world of fundamental constituents is a great achievement, on a par with the discovery of the periodic table and the beginnings of the invention of quantum mechanics. It shows the way toward a simple, organized explanation and understanding of everything that goes on in the universe at the most elementary level. However, as our conception of matter based on quarks and leptons

THE STANDARD MODEL



MATTER & ENERGY

FORCES

CONSTITUENTS

Strong — Gluon

Electro-magnetic — Photon

Weak — W, Z Bosons

Gravity — Graviton

Quarks

up	charm	top
down	strange	bottom

Leptons

electron neutrino	muon neutrino	tau neutrino
electron	muon	tau

has become better established, we have become increasingly aware of its shortcomings. Having arrived at a new level of understanding, we can look critically at our collective achievement and try to ask what we haven't succeeded in doing.

Since the late 1970s, the international scientific community has recognized that our new understanding is incomplete. We can define a frontier where the standard model ceases to make sense. The response sets the scale of the Supercollider: It is the scale of energies of about *one trillion electron volts* for the collisions between quarks and leptons and the force carriers. Or, if you like, it is on a very small distance scale: distances less than a billionth of a billionth of a meter. This is the place where our current understanding doesn't quite make sense, where there must be something new and interesting going on.

The questions about nature that are raised, but not answered, by our current model indicate the kind of initial exploration that we want to conduct with the Supercollider:

We want to know what determines the properties of the quarks and leptons, just as our scientific ancestors asked themselves what caused the elements to conform to certain patterns of behavior. We can arrange the known quarks and leptons in the little boxes shown in the figure and notice the relations between them, but how much more satisfying it would be if we could tell how much a quark or lepton will weigh and how it will behave under particular circumstances.

We have evidence for six quarks and six leptons, but we don't have any reason why there should only be six of each, or that there should indeed be six of each. How many of them are there? From a self-centered perspective, just having only two quarks and electrons would seem to be fine: that is the stuff we are made of. What role do the other quarks and leptons play in shaping the world around us?

There are many close similarities among the quarks and leptons. Indeed, mathematical consistency of the theory that brings radioactivity and electromagnetism together requires that there be a connection between quarks and leptons. For each set of quarks there has to be a set of leptons. How are the properties of the quarks and the leptons related?

All the direct experimental evidence so far is consistent with the quarks and leptons being fundamental. We haven't seen any structure inside them, but we recall that atoms, nuclei, and protons all looked fundamental at the time of their discovery. Yet, when they were scrutinized more closely, there was something inside, there were simpler constituents to be found. Are there even simpler and more fundamental things to be found inside the quarks and leptons? The observation of constituents within the quarks and leptons would give us a better understanding of the properties of today's fundamental constituents and the ability to construct a full picture of nature.

We may ask whether there are other kinds of matter, not made of quarks and leptons, that we haven't yet seen.

In addition to those questions that pertain to the constituents, there are some questions that have to do with the interactions. We have found a nearly complete connection between the weak interaction and electromagnetism. However, there is a fundamental difference between the interactions that we observe. Electromagnetism acts over very large—astronomical—distances. We can check the laws of electromagnetism out to interplanetary separations, and the influence of electromagnetism is felt at those vast distances. The weak interaction, which is friend and partner to electromagnetism, acts only over a range which is small even compared with the size of an atomic nucleus. What makes radioactivity and electromagnetism different and yet at the same time so similar?

Having seen the complete unification of electricity and magnetism in electromagnetism, and the partial unification of the weak and electromagnetic interactions, we may ask whether there is in fact an underlying unity among all the fundamental forces. We may also inquire whether there are new fundamental forces that we haven't seen before.

These questions—together with our appreciation of the countless instances when unexpected, puzzling, and ultimately illuminating new observations have come out of accelerator experiments—motivate our quest for a microscope capable of looking at even smaller distances: an accelerator of higher energies.

Physicists do not believe that within the energy range now available there are or will be enough clues for us to piece together a theory of the nature of matter. Both our specific questions and more general arguments set a scale of energy or size that we need to explore, the domain of energies of about a million million electron volts, of distances smaller than a billionth of a billionth of a meter. The instrument of choice for opening this frontier is one of the most extraordinary scientific instruments ever conceived: the Superconducting Super Collider.

The SSC

The Superconducting Super Collider (SSC) will be a chain of accelerators, linked to boost barely moving protons to nearly the speed of light. The particles reach increasingly high energies in a cascade of four accelerators that make up the injector, from which they are fed into the collider ring.

The collider ring will be the heart of the SSC. In this underground oval tunnel, ten feet in cross section and fifty-three miles in circumference, two beams of protons will be accelerated in opposite directions. Superconducting electromagnets in the collider ring will guide each proton beam through a stainless steel pipe about one and a quarter inches in diameter. Magnets will curve the paths of the beams, making it possible to build the accelerator in a loop, rather than a straight line, and thus realize substantial economies by repeatedly using the same components to accelerate and contain the beam. The protons will travel in compact bunches, with some eight billion protons in each bunch. Each second, the fifteen thousand bunches that will fill each beam pipe will make three thousand laps around the ring. On every lap, a pulse of radio waves will boost the energy of each bunch, until the protons reach their final energy—twenty trillion electron volts. The two circulating beams of protons will be maintained at that energy and focused into head-on collisions where detectors will record particles produced from the energy of the collision.

Superconducting magnets will be used because they make possible substantial cost savings, both in construction and in operation of the SSC. At low temperatures, certain materials become superconductors. A superconducting material dissipates no energy in heat—it just carries the current you put into it *without electrical resistance.* Such a material, an alloy of niobium and titanium, will be used to fabricate the coils for the SSC magnets. The coils are made of copper wires, inside of which are embedded thousands of fine fibers of niobium-titanium alloy, each about one-sixth the diameter of a human hair. It is those niobium-titanium fibers that carry the current. When cooled to the temperature of liquid helium, about four degrees Kelvin above absolute zero, each one of the strands is capable of carrying about five hundred amperes. That is twenty or thirty times what a slightly bigger wire carries in a house before the fuse blows. Once the SSC magnets are turned on, electric power is only required to run the refrigerators that keep them cold, not to replenish the current in the magnet coils. A non-superconducting supercollider with conventional magnets would require four gigawatts of electrical power, resulting in an electric bill of about one billion dollars per year. The SSC's average power requirements are about forty times smaller. In addition, superconducting magnets can create magnetic fields several times stronger than conventional magnets, thus confining the protons to a tighter orbit and reducing the ring's circumference.

At the interaction regions the two beams will be steered into head-on collision. The protons' vast energy, concentrated in a minute volume, will materialize in a brief flash of new particles. International teams of scientists will design and operate experimental apparatus to identify the particles produced and to determine as precisely as possible the path each particle follows. Although similar in concept to existing detectors, SSC detectors will be larger and more complex: a typical detector will weigh about 50,000 tons and will require a million channels of electronics to filter out the interesting events from the 100 million collisions that will occur every second.

Although many of the phenomena that will be revealed do not occur at the relatively low energies of ordinary conditions on Earth, they play a crucial role in the unification of forces and in the dynamics of the very early universe. If the history is any guide, this deeper understanding that will allow us to codify the basic laws of nature will eventually result in putting that knowledge to humane and productive use.

The Connections of Elementary Particle Physics with Other Sciences

Elementary particle physics does not exist in isolation, either as a scientific discipline or as a technological enterprise. Stimulation, information, and techniques flow both ways: from other activities toward particle physics, and from particle physics toward other activities.

The intellectual links to other sciences are strong. They grow more robust as our own field of elementary particle physics develops a greater unity and coherence. Quantum chromodynamics, a theory of the strong interaction between quarks, finds applications and some of its most probing tests in nuclear physics. We share with our colleagues in atomic, molecular, and optical physics an interest in tests of quantum electrodynamics and measurements of the fundamental properties of the electron, muon, and other basic particles. In the last decade, a close working relationship has developed between elementary particle physicists and astrophysicists and cosmologists concerned with the evolution of the universe. The laws of nature uncovered in the study of particle physics are essential ingredients in imagining what the early universe must have been like. Astrophysical relics from those early moments when the universe was small, hot, and dense test our ideas about the fundamental interactions at higher energies than we will ever be able to attain with accelerators.

Much of our insight into the nature of complex systems built up from simple components and simple rules comes from the science of condensed-matter physics. We share with this field many theoretical tools, and an interest in hidden symmetries and changes of phase, or state. Traditional connections between theoretical particle physics and mathematics are once again in great ferment, with the recognition of the common ground shared by fibre bundles and the gauge theories of the fundamental interactions, with the rich interchange between new mathematics and superstring theories, and with the emergence of the interdisciplinary study of complex (nonlinear) systems called "chaos."

The health of these other fields of basic research is essential to the vitality of elementary particle physics and the advance of basic research requires vigorous progress in particle physics.

Particle physics also enjoys strong links to new technologies. A few examples will serve to illustrate how benefits flow both to and from elementary particle physics. Synchrotron light sources, the offspring of accelerator science, now find routine application to materials research, biomedical studies, and the fabrication of electronic components. The high-density semiconductor devices manufactured in this way are important elements of the detectors used in elementary particle physics experiments. Advances in the capability of the niobium-titanium superconducting cable so essential to the Supercollider (and to the availability of magnetic resonance imaging devices for medical diagnosis) have resulted from a purposeful collaboration among accelerator builders, university-based metallurgists, and industrial firms. The demands of particle physics have spurred the development of fast electronics and new computer architectures to handle high data rates, and to make the rapid decisions required by modern detectors. Theorists, experimenters, and accelerator builders are quick to take advantage of new capabilities spawned elsewhere in networking, the application of remote local intelligence to process control and engineering design. The components of our detectors, including semiconductor devices, tracking chambers, and calorimeters, also provide fruitful interchange with other researchers, manufacturers, and developers of technology in fields such as medical imagery.

A Brief History of the SSC

Although the scientific need for a step to much higher energies was already apparent, in broad terms, a decade ago, it was necessary to develop the technical means to take that step. Formal studies of the feasibility of a multi-TeV accelerator began with workshops sponsored by the International Committee on Future Accelerators at Fermilab in 1978 and at CERN in 1979. Various possibilities for very high energy accelerators, including proton-proton colliders at tens of TeV per beam, were examined. The idea of the SSC began to take shape at the 1982 Summer Study on Elementary particle Physics and Future Facilities organized in Snowmass, Colorado, by the Division of Particles and Fields of the American Physical Society. The SSC initiative was followed up with workshops on accelerator and detector issues held during 1983 at Cornell University and at the Lawrence Berkeley Laboratory.

Encouraged by the successful operation of the Fermilab Tevatron (the first superconducting synchrotron), where protons have been boosted to energies of nearly one trillion electron volts, a High Energy Physics Advisory Panel (HEPAP) Subpanel on Future Facilities recommended "the immediate initiation of a multi-TeV, high-luminosity [high collision-rate] proton-proton collider project with the goal of physics at the earliest possible date." This recommendation was transmitted to the Department of Energy with the unanimous endorsement of HEPAP in July of 1983. The DOE responded by reprogramming, with Congressional approval, of funds for preliminary R&D for the SSC in the fall of 1983. Since that time, on two separate occasions—once in 1985 and once in 1989—comprehensive reviews by HEPAP of the U.S. high energy physics program reaffirmed the timely construction of the SSC as the number-one priority in that field.

In December 1983, the DOE and the Directors of the United States high-energy physics laboratories chartered a Reference Designs Study. The goal was to produce example designs of a proton-proton collider that would yield about 100 million collisions per second with energy of 20 TeV per beam. Three different approaches were investigated, and it was found that any of them could form the basis of a technically feasible SSC, at a cost of approximately three billion (FY 1984) dollars.

Early in 1984, the Department of Energy contracted with Universities Research Association, a consortium of leading research universities, to direct and coordinate the SSC research and development program. For this purpose the SSC Central Design Group (CDG) was established, accepted the hospitality of the Lawrence Berkeley Laboratory, and began work on a non-site-specific conceptual design. Other participants in this national effort included Brookhaven National Laboratory, the Fermi National Accelerator Laboratory (Fermilab), Lawrence Berkeley Laboratory, the Texas Accelerator Center, and experts from many laboratories and universities in Canada, Western Europe, Japan, and the United States. American industrial firms also played an important role.

Since approximately 8000 dipole magnets will generate the magnetic field that keeps the protons circulating around the SSC collider rings, an early goal was to determine the basic dipole magnet style. In September 1985, after several different concepts had been developed and studied, a high-field superconducting magnet, in which the field is defined by the placement of the superconductor, was adopted as the basis for the conceptual design.

Simultaneously, all accelerator and conventional systems (other than detectors) were defined and assessed. The completed Conceptual Design Report (CDR) details the scientific, technical, and cost aspects of the project. Since its publication in March 1986, the Conceptual Design Report (SSC-SR-2020) has been extensively reviewed by independent experts. The reviews of this document formed the basis for the decision in January 1987 by President Reagan to endorse construction of the SSC as a Presidential initiative. Subsequently, the Conceptual Design Report has served as the basis for continuing SSC R&D.

Selection of a Site and a Management and Operations Contractor

The Department of Energy initiated the SSC site selection process in April, 1987, by issuing an invitation for site proposals which described the facility, the site selection criteria, and the selection process to be followed. DOE asked the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE) to form an evaluation committee which would review the qualifying proposals and identify several best qualified ones.

Forty-three site proposals were submitted and thirty-six of these were judged by DOE to satisfy their qualifying criteria. Those proposals were forwarded to the NAS/NAE committee for evaluation and in December, 1987, that committee submitted a report identifying eight of the sites as the best qualified ones (one of these eight was subsequently withdrawn by the proponents). The DOE concurred with the recommendation of the committee and initiated detailed evaluation of the seven remaining sites.

As a result of this evaluation process, the Texas site, located in Ellis County, was designated the preferred SSC site by the Secretary of DOE in November, 1988. Pursuant to subsequent study of the environmental impact, the preferred site was designated the SSC site on January 18, 1989.

In August, 1988 the DOE issued a call for proposals for management of the construction and, as an option, of the subsequent operation of the SSC Laboratory. Experience in high energy physics activities and in construction of large-scale projects were deemed the most important criteria in the selection process. The Universities Research Association, a consortium of then sixty-six leading research universities, submitted a joint proposal together with two industrial companies, EG&G and Sverdrup. This proposal was accepted and the URA team was designated as the SSC M&O contractor on January 19, 1989.

Priorities for the Next Eighteen Months

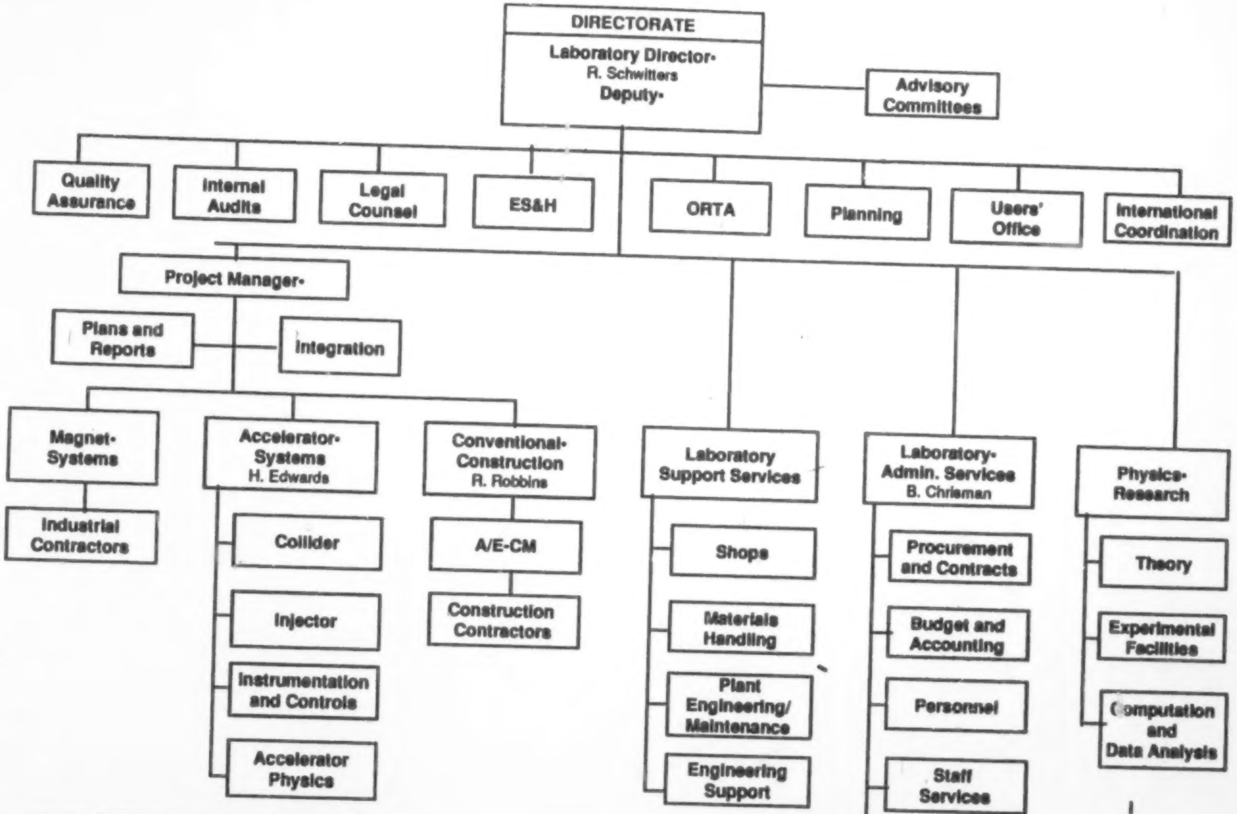
The selection of the SSC site in Texas and of the M&O contractor, URA, allow us now to proceed with the tasks that are necessary to build a new high energy physics laboratory. In embarking upon these tasks we are fortunate that we are able to start from the foundations established by the four years of R&D work performed under the leadership of the SSC Central Design Group.

We anticipate that many of the senior people from the CDG will form the core of the leadership at the new SSC laboratory and we hope that the large majority of its dedicated staff will join the new SSC organization. The continuation of the R&D and the initiation of the construction phase will, of course, require a significant growth in the staffing level; we are beginning to embark on the recruiting task, hoping to find and hire the best people in the world for the key positions at the laboratory. Our goal is to build up, over time, a technical staff that will operate the laboratory once it is completed. To fill the personnel "bulge" that will occur during construction, we plan to rely on our two industrial partners, Sverdrup and EG&G. Industrial involvement will be critical to the efficient construction of the laboratory. It is our intention to subcontract with private industry for a number of manufacturing and construction activities and, in the operational phase, for various specific tasks required at the laboratory.

The next several months will be a period of transition, both geographic—from Berkeley, California, to Ellis County, Texas—and organizational—from the SSC Central Design Group, the organization that carried out the pre-construction R&D mission, to the SSC Laboratory. We are currently in the process of defining the new SSC organizational structure, and our current thoughts on this subject are presented in the attached organization chart.

We have already obtained limited office space not far from the site that will become the nucleus of the activities associated with the new laboratory. A very important part of our transition activities is the re-evaluation, in light of the recent SSC developments, of the budget priorities during FY89 consistent with the Congressionally mandated prohibition of construction activities..

The Conceptual Design Report is still the most authoritative source on the design and the cost of the Supercollider. Since its completion, several important new developments have occurred which might have some impact on the design and cost of the facility. Foremost among them is the selection of the site, which allows us now to go ahead with the preparation of the site-specific conceptual design. The research and development work conducted during the last three years, both theoretical and experimental, has yielded new information that will result


DIRECTORATE
Laboratory Director•
R. Schwitters
Deputy•
Advisory Committees
Quality Assurance
Internal Audits
Legal Counsel
ES&H
ORTA
Planning
Users' Office
International Coordination
Project Manager•
Plans and Reports
Integration
Magnet• Systems
Industrial Contractors
Accelerator• Systems
H. Edwards
Collider
Injector
Instrumentation and Controls
Accelerator Physics
Conventional• Construction
R. Robbins
A/E-CM
Construction Contractors
Laboratory Support Services
Shops
Materials Handling
Plant Engineering/ Maintenance
Engineering Support
Laboratory• Admin. Services
B. Chrisman
Procurement and Contracts
Budget and Accounting
Personnel
Staff Services
Technical Information
Physics• Research
Theory
Experimental Facilities
Computation and Data Analysis

•KEY PERSONNEL FROM RFP/DRAFT CONTRACT

Proposed Laboratory Organization

in modifications and improvements of many technical components of the facility. Finally, the vigorous effort that has been extended worldwide in various workshops on physics opportunities at the high energy colliders has resulted in a better understanding of the requirements for the experimental halls where the detection apparatus will be located. This information will allow us to define more precisely the design of the experimental areas.

The cost estimates given in the Conceptual Design Report stand as an accurate representation of the total cost of the SSC facility. It is prudent and customary to reexamine the total estimated cost of any construction project on an annual basis. Accordingly, we plan to obtain an updated, bottoms-up cost estimate of the SSC, using the new information available, and we hope to have this completed during the next year. This cost estimate will be performed in parallel with an extensive review of the whole project by the Director. Our intent is to assure that the SSC Laboratory can be built, and then operated, efficiently and on time, within the budget limits now specified.

The research and development effort will continue to have maximum priority and will build on the work initiated by the Central Design Group. Development of optimum and cost-effective superconducting magnets will be pursued vigorously. Any R&D program sorts out competing designs, identifies and corrects flaws in design and process, and prepares for transition to final manufacture in the most efficient manner. Even though the superconducting magnet R&D program for the SSC has encountered many complex and difficult problems, most of those have already been solved and, as of today, two full-length magnets meeting SSC performance specifications have been produced. The work that has been carried on heretofore at the laboratories will be augmented by the efforts of private industry within the framework of the magnet industrialization program, a program that is now under way and that has been characterized by active and enthusiastic participation by U.S. and world industry.

In parallel we shall pursue technical design of the injector system, continue our studies of beam dynamics in the SSC, enlarge the scope of work on cryogenics and other accelerator systems, and increase our efforts on the SSC detector systems. This latter effort will be carried on principally at universities and laboratories all over this country, and abroad as well. The R&D goals for FY90 are discussed in more detail in another section of this presentation.

The purpose of the SSC is to investigate the fundamental laws of nature, and thus the organization and initiation of the scientific program will be a very high priority during the next eighteen months. The SSC will be a leading instrument in the field of high energy physics and a major focus of interest not only of a majority of the U.S. particle physics community, but also of a significant fraction of scientists abroad. To assure the highest quality scientific program at the SSC, I plan to appoint soon an International Scientific Policy Committee to advise me on formulation of the guidelines and time scales for the initiation of the physics research work at the SSC. We shall continue the CDG tradition of sponsoring workshops on both technology and physics that are relevant to the SSC, and anticipate wide involvement of the whole U.S. high energy physics community in these efforts. At a somewhat later date, I plan to appoint a Program Advisory Committee, with a function of providing advice about specific aspects of the experimental program.

It is the stated intention of the U.S. government to seek foreign participation in the construction of the SSC. The establishment of the SSC Laboratory administration and the demonstration of a commitment to move ahead with the laboratory will now allow us to take concrete measures to achieve that goal. It is our intention to embark immediately on high-level contacts with our senior colleagues abroad as well as with science administrators in foreign countries with the objective of defining clearly their interest and our own, and examining their potential to provide specific systems and subsystems for the SSC. These contacts will build on demonstrated extensive interest from scientists abroad in utilization of the SSC that has exhibited itself in extensive foreign participation in various technical and scientific workshops. The appropriate administrative conditions are now being put in place to allow us to initiate efforts to translate these interests into specific commitments to participate in SSC construction. We feel that U.S. commitment to this project is essential if we are to be successful in our efforts with our foreign colleagues.

Budget Summary

With the selection of the site for construction of the SSC, the efforts of the CDG design team are about to be realized. URA, as the M&O contractor, is prepared to continue the design work for the SSC and looks forward to the eventual operation of the research facility on behalf of the Department of Energy for the benefit of the country and the high energy physics community.

The budget request presented here outlines funding for research and development and for construction. Considerable research and development attention is directed toward the design, production, and testing of long and short superconducting magnets. Brookhaven National Laboratory will continue to produce prototype yoked magnet coils for insertion into helium cryostats at Fermilab. (BNL will also have its own limited capability for cryostating and testing magnets.) The superconducting cable developments will be centered in industry with supervision and coordination by the Lawrence Berkeley Laboratory and SSC personnel. In addition, Fermilab will be expected to fabricate long and short magnets for testing in the magnet test facility.

Long lead-time procurement of material such as superconducting cable will be needed to set the stage for the subsequent steps of magnet coil winding by industry. R&D funds will be used in FY 1989 to acquire additional cable-making machines. These machines will be provided as government-supplied equipment to the successful industrial superconducting cable suppliers for the SSC production needs in 1990 and beyond.

The other portion of the budget request concerns the use of construction funds for the project, much of which will be directed toward the design of the technical components for the accelerator facilities and the start of long lead-time items. The main item is the continuation and expansion of the Magnet Industrialization Program. Following the technology orientation phase of the program a selected number of vendors will be invited to design and fabricate production-quality tooling prototypes for the pre-production of superconducting collider dipole magnets. Emphasis will naturally be placed upon the successful production of a substantial number of magnets—magnets that when cooled and tested meet the performance objectives.

Fiscal year 1990 represents the start of preliminary design efforts for numerous technical components for the SSC. The requirements for the superconducting quadrupoles must be refined so that pre-production units can be made. Design of cryogenic elements that connect the quadrupoles to the ring dipoles will be completed and this will permit completion of the preliminary design efforts for the overall collider ring cryogenic system. Other important design objectives are centered on the injector. Following determination of the energy of the proton beam to be injected into the collider, the final design of the high energy booster can proceed. An important related topic concerns the test beams to be provided from the injector. Early availability of those facilities will be crucial to the testing of components for the SSC detectors.

Progress with siting studies will allow precise determination of the location of the large collider ring on the Texas site. It is expected that the campus area will be identified and plans begun for the construction of laboratory facilities. One of the most important will be the Magnet Test Laboratory. This facility will be needed to prepare, cool down, and test the superconducting magnets produced by industrial suppliers. It will play an important role in qualifying magnet vendors as well as serving as a quality control facility in the future.

The development of site facilities will require the procurement of electrical transmission line and substation equipment. Such capabilities will be needed in the campus area for the Magnet Test Laboratory, and will be required for the commissioning of technical systems. Procurements need to be initiated for such long lead-time items as substation transformers, switchgear, towers, and cable for electrical distribution.

Finally, increased attention will be given to the preparation of detector systems for future experiments at the SSC. Universities, laboratories, and industries are expected to participate in the research and development activities on detectors. The testing of components, needed to support the design and construction of these detectors, will be done in the initial stages mainly at Fermilab, with some testing being carried out at other laboratories both in the U.S. and abroad.

SSC FY90 PROGRAM

(PRESIDENT'S BUDGET REQUEST)

		FY90 M$
Construction Program		160.0
• Technical Systems design	29.0	
• Conventional Systems design	29.0	
• Site preparation, utilities and support buildings	24.0	
• Technical Systems – Advanced procurement and magnet industrialization	50.0	
• Support equipment and rental space	10.0	
• Project Management	18.0	
R&D Program		90.0
• Accelerator component development	59.0	
• Detector Systems design and development	19.0	
• Accelerator development equipment	12.0	
TOTAL PROGRAM		250.0

The R&D Program

Superconducting Magnets. The principal goal and focus of the SSC magnet program in FY89 is the completion of the baseline design for the SSC collider dipole magnet. Both the superconductor and the magnet mechanical design aspects are reaching completion in that year with the fabrication and testing of six full-length baseline model dipoles and a comparable number of short magnet versions of the same design. Alternate R&D versions of the baseline design incorporating aluminum collars or axially-free collared coils were also tested in full-length development model magnets.

From this program, a magnet baseline design will be achieved and prototypes tested by the end of the fiscal year. The attached development logic diagram summarizes the decision process, and the attached figures show the performance of two successful full-length prototypes as well as the results of the test of a short magnet utilizing current design. The baseline model will meet all SSC systems requirements for the collider dipole application, and the resulting design will serve as an appropriate departure point for development in industry of a production version of the collider dipole and its associated production tooling. The FY89 magnet measurement and testing program will experimentally establish achievement of the needed magnetic field quality for service in the SSC collider as well as demonstrate the required mechanical, electrical, and thermal qualities to meet the SSC single magnet system needs and requirements. In addition, development of the collider quadrupole magnet design will be initiated in FY89.

It is the clearly stated policy of the SSC that the full complement of collider dipole magnets required for the project will be constructed in industry, and our Magnet Industrialization Program has been planned to carry out this task. The first phase of this three-phase program, the transfer of laboratory-originated technology to industry, is in progress and will be completed

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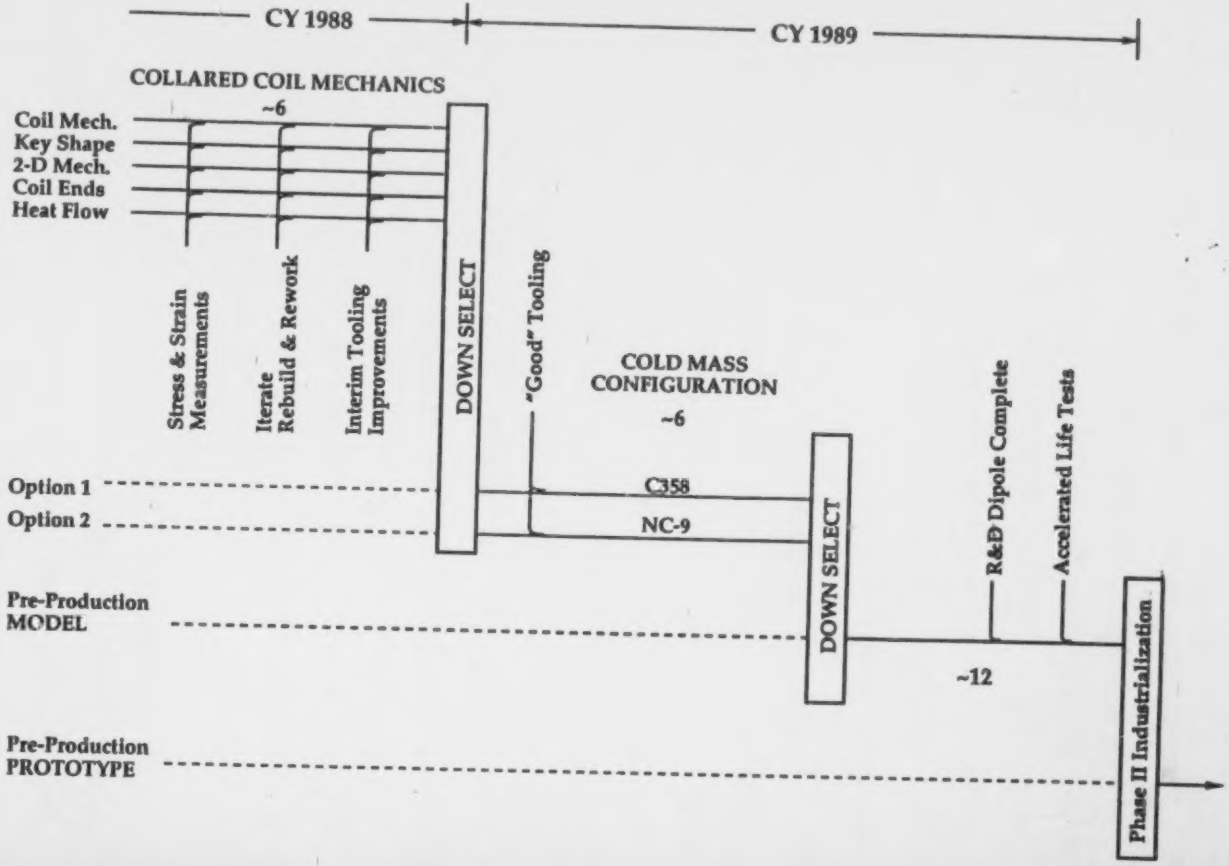
SSC Collider Dipole Development Logic


CY 1988
CY 1989
COLLARED COIL MECHANICS
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Coil Mech.
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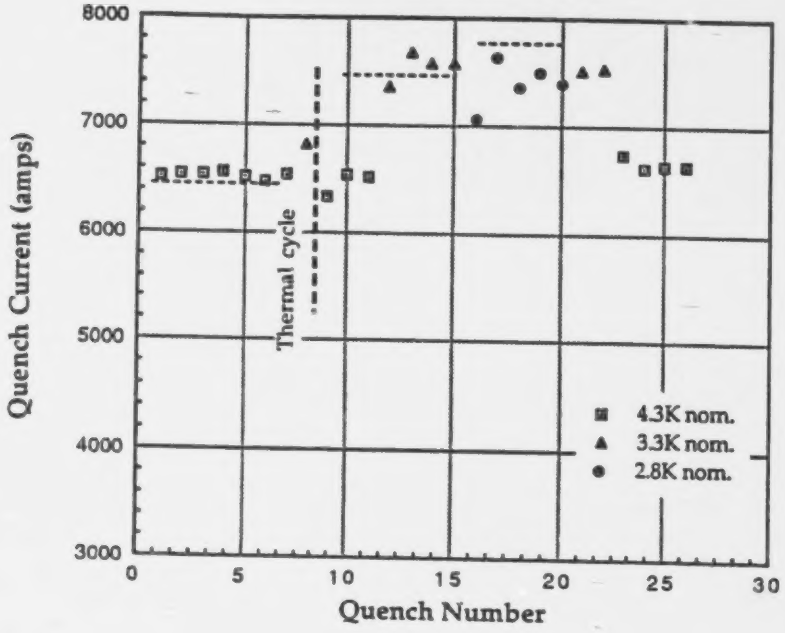
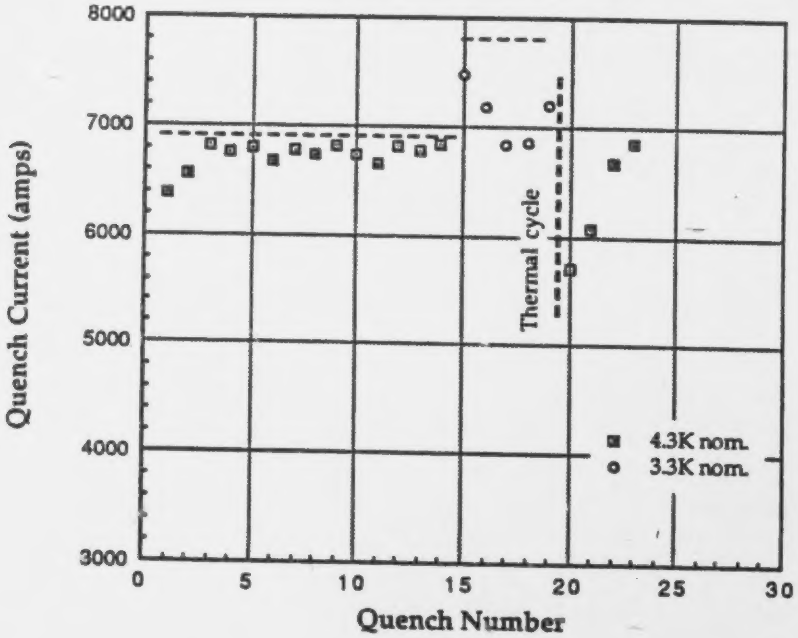
2-D Mech.
Coil Ends
Heat Flow
Stress & Strain Measurements
Iterate Rebuild & Rework
Interim Tooling Improvements
DOWN SELECT
"Good" Tooling
COLD MASS CONFIGURATION
~6
C358
NC-9
Option 1
Option 2
Pre-Production MODEL
Pre-Production PROTOTYPE
DOWN SELECT
R&D Dipole Complete
Accelerated Life Tests
~12
Phase II Industrialization

Recent Test Results
Full Length SSC Collider Dipoles

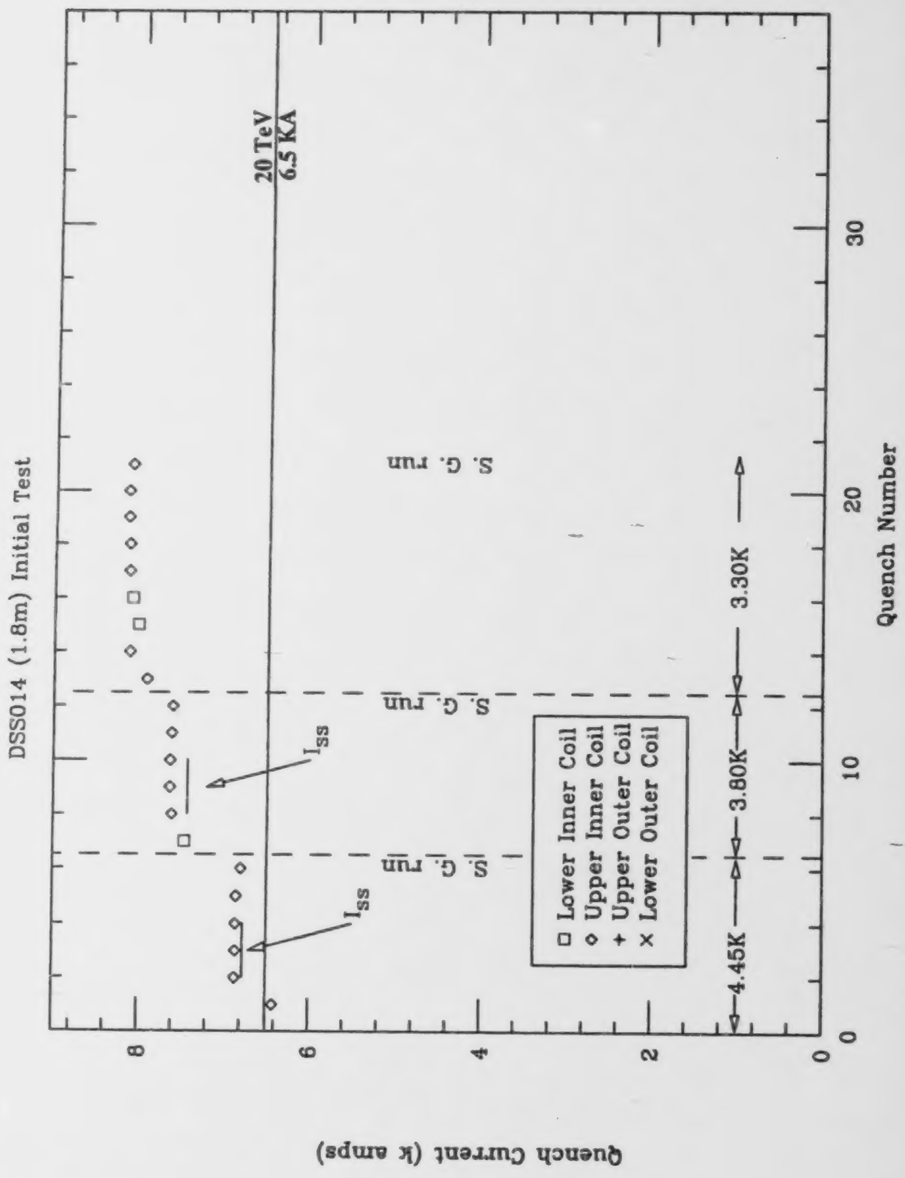
DD0012: Current at Quench



DD0014: Current at Quench



Current Design Version
SSC Collider Dipole - 1.8m Model
Quench Test Results, DSS014



by the end of February. The industrial response to this program has been very positive. We plan to issue a Request for Proposals for the industrial development of coil tooling and coils during this fiscal year. The currently anticipated timeline for the industrialization process leading to the industrial production of the superconducting dipoles is shown in the attached figure.

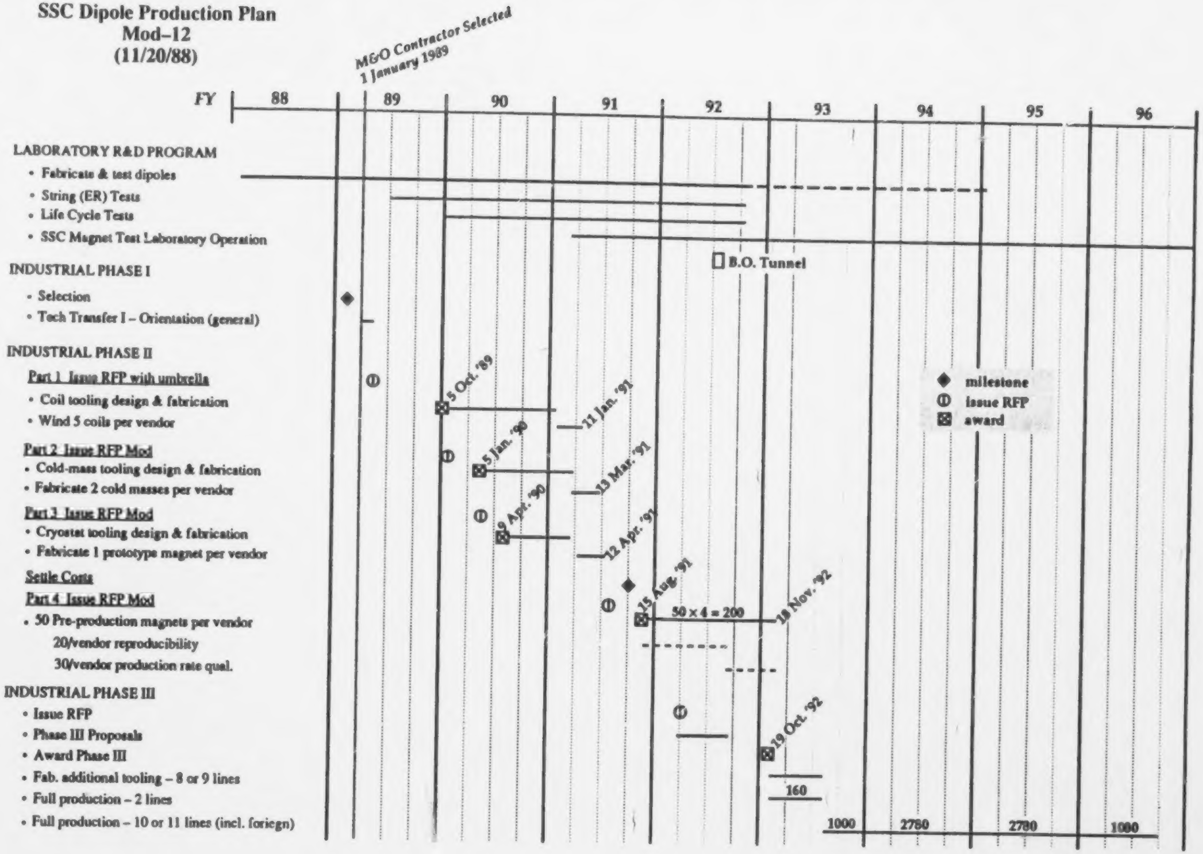
The emphasis for FY90 in the R&D program will turn to experimental demonstration of achievement of life-test and cryogenic system requirements. This objective necessitates that several magnets be hooked up and operated together. This program will be accompanied by continued production of baseline R&D dipoles in the laboratories. The magnets will be used for the systems tests noted above as well as to measure the variation in their field-quality parameters to verify that this variation in the final ensemble of magnets is consistent with expected distribution.

Development of the collider quadrupole will be continued in FY90, and conceptual and preliminary design for the high-energy booster dipole will be initiated in FY90. The very successful industrially based R&D on superconductors will continue with a focus on production scale-up techniques to meet SSC project needs. The progress achieved so far in increasing the current-carrying capability of the superconducting cable is illustrated in the accompanying figure.

Although the mechanism for the industrial production of coils will be set in motion in FY89, it is expected that the first orders for industrially produced coils will be placed at the beginning of FY90. Current plans call for contracts with four or five vendors to adapt the R&D coil design for production and coil production tooling. These initial contracts for coil production will be followed by contracts for the production of prototype cold masses and cryostats starting toward the end of FY90.

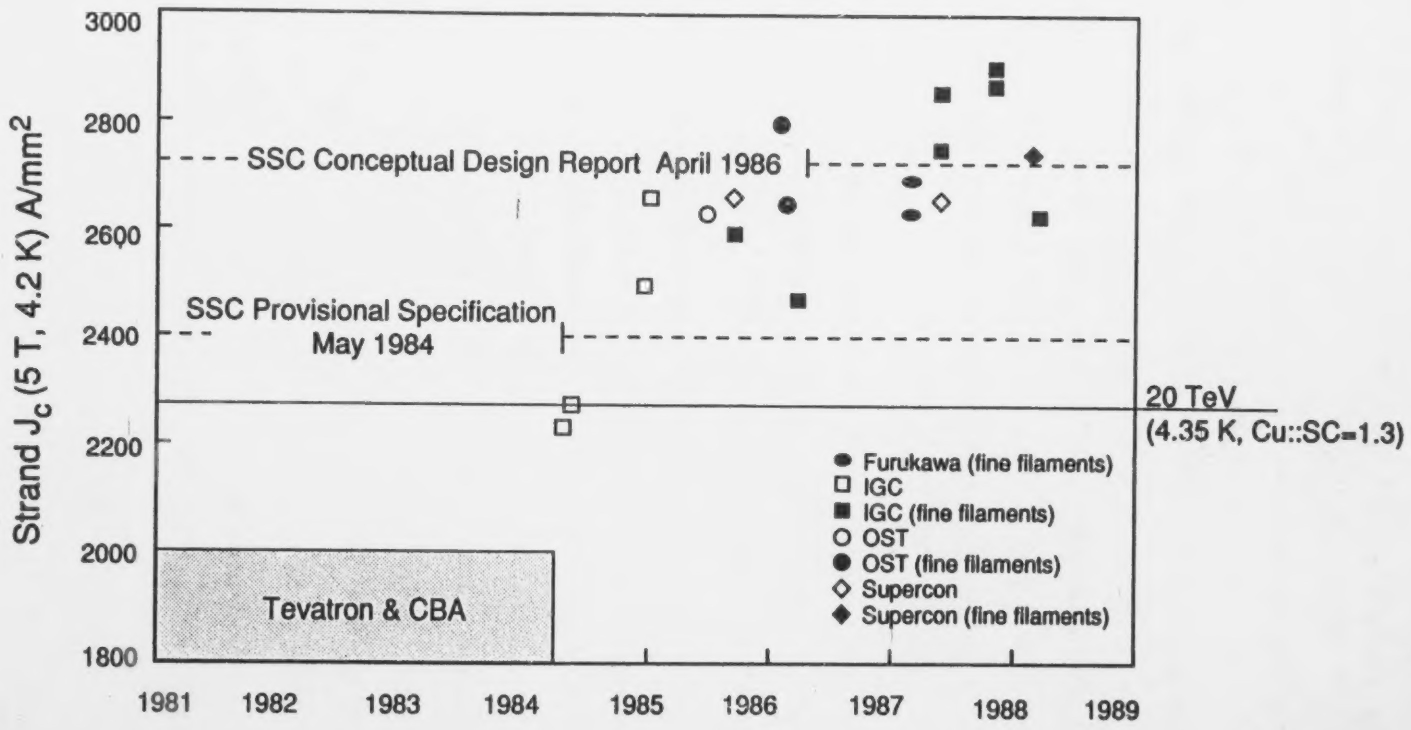
CDG Proposed

SSC Dipole Production Plan
Mod–12
(11/20/88)



Time Development of SSC Superconductor

December 1988



Accelerator Systems. Within this area fall the R&D and design of accelerator components and systems, their integration, and studies and R&D about various phenomena that might affect machine performance. Initially, the design work was largely limited to conceptual designs. Most of the effort was spent in understanding the behavior of accelerator systems and in building tools, such as computer simulation, that will be necessary for the detailed design of the machines. Because the SSC R&D during this phase was concentrated on the superconducting magnets, the Accelerator Systems Division devoted most of its work to systems that interface directly with the magnets. These included, in addition to the magnet systems themselves, cryogenics, vacuum considerations, quench protection, radiation calculations, correction elements, and controls.

The major magnet-systems activities in the past year have been in three areas—dynamic and static thermal calculations, specifying and designing the Magnet Test Laboratory, and integration of the magnets with other systems.

Thermal Calculations: Software has been written to simulate the thermal behavior of the magnet system under cooldown and warmup, and a lumped-element thermal model of the magnet, written under contract by General Dynamics, has been commissioned at the CDG. These studies are particularly important in guiding the choice of design details and materials for the magnet R&D. Insulation and cryogen flow schemes can be studied and evaluated, and the results integrated into the magnet design. The integration effort is significant because the magnet designs are progressing rapidly on many fronts.

The Magnet Test Laboratory (MTL) effort is now far along, and we are reviewing the Request for Proposals before issuance. This facility is intended to be built on or near the SSC site, and to be ready to test 80 prototype magnets from industry during 1991. Eventually, it will be capable of handling 10 to 15 percent of the peak magnet production rate for warm and cold testing.

Cryogenics System: The activities of the past year in cryogenics involved commissioning dynamic simulation software for studying the behavior of the collider ring cryogenic system and establishing useful models of the collider refrigerators in process calculations. The dynamic software was written under contract by Air Products and Chemicals, Inc., and is run on the Lawrence Berkeley Laboratory VAX cluster by CDG personnel. It has been modified by the CDG Accelerator Systems Division to operate interactively on the SUN Microsystems workstations. This software has been found to be extremely useful for investigations of appropriate control strategies to be used in the cryogenic system, and has already shown that some changes must be made. Since it now operates interactively, it will be the base for testing the cryogenic controls system software.

Vacuum Systems: The effort in vacuum systems over the last few years has been to understand the influence of synchrotron radiation on the behavior of the vacuum in the beam tube. In previous years we had demonstrated by experiment at the National Synchrotron Radiation Laboratory at Brookhaven that the pressure rise due to photodesorption will not significantly decrease the luminosity lifetime of the collider. In the past year we have performed a series of experiments at the Synchrotron Radiation Laboratory in Stoughton, Wisconsin to measure independently the photodesorption parameters. These measurements have been published and confirm our previous conclusions. A collaboration with KEK in Japan is continuing to study the effects of magnetic fields on the desorption rates. Preliminary conclusions indicate that the presence of magnetic field is in our favor. An improved experiment will be run in 1989.

Quench Protection: The high-current bypass diodes that would be used for passive quench protection must be operated at liquid helium temperatures in a radiation environment. A CDG–Texas Accelerator Center–Texas A&M University collaboration has been studying the effects of neutron radiation on various diodes. In the past year, it has been shown that at least one diode, the DS6000 of Asea Brown Boveri, Inc. (ABB), is adequate for the SSC, having an effective lifetime greater than 100 years in the presence of neutron fluxes that will be present in the SSC tunnel. We are currently negotiating with ABB to perform other tests that will inform us about the basic reliability of the diode.

Radiation Calculations: We are continuing calculations to understand the radiation intensities, their types, and their spectra in the SSC tunnel and experimental areas. These calculations are important for the accelerator systems and serve to inform us about materials to be used to ensure that electronics can survive in the tunnel. There are numerous collaborations with other institutions, including Fermilab, Oak Ridge National Laboratory, and Livermore National Laboratory. All this work is coordinated and published through the CDG.

Correction Elements: The correction elements are used to correct the systematic and random multipole errors in the dipole and quadrupole magnets. The major effort here has been in two areas—a study of the effectiveness of various correction element schemes and the start of R&D and prototyping work on correction elements. The Correction Element Working Group (CEWG) was formed to study the various possible schemes of correction elements in the collider rings. The first report has been issued, discussing the response of each scheme to expected systematic and random magnet errors and random orbit errors, using both simulation code (TEAPOT) and analytical methods. There appear to be a number of useful and practical correction schemes, but some possibilities are clearly not as good as others. This work will be continuing in more detail in 1989.

Control Systems: Our first efforts to understand the structure of the controls software was begun in 1988. The work concentrated on understanding what sort of database software and general architecture was needed and available, and how one could guarantee compatibility among different types of hardware. A considerable amount of progress was made, particularly associated with constructing databases and communications for data from the magnet tests at Fermilab and Brookhaven National Laboratory.

Accelerator Physics. The accelerator physicists working on the design of the SSC complex have several important tasks: the optimization of the accelerator design itself, including the linac, the injector complex, the main SSC accelerator, and the experimental interaction regions; the detailed specification of performance requirements and tolerances for machine technical components; the development of algorithms and techniques to monitor and control the performance of the accelerator complex so as to maintain the maximum collision rates; and the study of accelerator physics to develop new methods of accelerator design and operation.

The design of the accelerator complex includes the design of the several injectors required for the SSC. The entire injector complex, similar to previous large accelerators, consists of an ion source and a linear accelerator chain, followed by three cascading booster synchrotrons. The proton beam originates in the ion source, is transported between different injector complex components, and is finally injected into the collider ring. Designs have been prepared for the injectors.

The proton beams in the SSC must be very carefully guided around the machine's 53-mile circumference, and they must be tightly focused to remain within the vacuum-pipe aperture. In addition, the machine design must include special experimental regions, as well as long magnet-free regions in which to perform necessary machine functions, such as beam injection, acceleration, and extraction. An arrangement of magnets around the machine circumference that incorporates all of the desired functions has been designed. This design is the result of an extensive optimization of machine performance, ease of operation, reliability, and cost.

An important part of the machine cost optimization is the size of the vacuum-pipe aperture inside the magnet. To minimize the machine cost, the aperture must be as small as possible, consistent with reliable machine operation. Many accelerator calculations and experiments have been performed to determine the minimum acceptable aperture for the SSC.

The design of the experimental sections of the SSC requires highly sophisticated magnet optics to satisfy the different kinds of experimental demands on the beams. Very tightly focused beams are required at the beam-collision points in order to produce the maximum number of proton-proton collisions possible. Arrangements of bending and focusing magnets within the experimental regions have been developed that allow the beams to be compressed at the collision points into cylinders very much smaller than a human hair. By varying the amount of quadrupole focusing in these regions, a wide range of beam conditions at the collision points can be explored, to accommodate a broad range of physics interests. Several different interaction region optical designs have been developed, appropriate for different types of experiments. Additional interaction region designs are under development. The precise configuration and complement of experimental regions in the SSC will be determined in response to requests for experiments from the physics community.

An important difference between the SSC and all previously built accelerators is its extremely large scale, necessitated by the goal of achieving collisions between protons accelerated to twenty trillion electron volts. Because of the size and number of different accelerators in the complex, and the very large number of elements required for the SSC itself, the system tolerances must be tightly set in order to insure the ease and reliability of operation.

To achieve such operation, one must develop a scheme to correct the systematic and random multipole errors in the dipole and quadrupole magnets. Accelerator physicists, together with the members of the Accelerator Systems Division, continue to develop different schemes with which to correct these magnetic errors. Highly efficient correction-element designs are under study.

Conventional Systems. The primary objective of recent work in the Conventional Facilities Division has been to understand the characteristics—particularly the topology and geology—of the Dallas site. In preparation for environmental and land acquisition efforts, the precise location of the magnet quadrupoles was calculated. The layout was then translated and rotated to adapt the footprint to the Texas site. Finally, the locations of the magnets and other components have been determined in the Texas state planar coordinates.

Computerized drawings that capture the site-specific information information on the existing and proposed man-made features at the site and in the near vicinity—electrical utility distribution lines, water supply sources, gas lines, roads, etc.—have been prepared under our direction by the engineering firm, RTK.

The Texas proposal describes a site with attractive geological properties: the ring tunnel will be largely in chalk and marl. Several profile studies of the tunnel in the geological strata have been prepared. Conceptual designs of several structures and enclosures have been undertaken. One example of an underground experimental chamber has been prepared in sufficient detail to allow the estimation of the duration of time for construction. Other studies in this area will continue as the designs of technical components are made final.

The primary technical goal of the conventional systems group for FY 1989 is to prepare a site-specific "footprint" for the SSC. The underground complexes are particularly important, since their placement is the principal factor in determining the final configuration of the SSC.

All the information available about the chosen site will be assembled and a program for collecting supplementary underground geotechnical data and topographic data required to support the conceptual design will be developed. Following the determination of the technical issues, the engineering firm will be expected to undertake a cost estimate for the conventional facilities and to generate a tentative schedule for construction.

A preliminary design for the Magnet Test Laboratory (MTL) to support the testing of superconducting magnets at or near the site by the end of 1990 will be undertaken this fiscal year. Additional work will focus on technical systems and their interfaces with conventional systems, such as the below-ground transport system.

In FY 1990, detailed plans, drawings, specifications, and bid documents for the first underground sectors need to be prepared using the conceptual design and geotechnical data. Current objectives call for beginning work on the following items:

- Near Cluster tunnel, including special sections, such as those needed for injection, rf acceleration and ejection systems.
- Heavy works buildings for component assembly and/or testing (at or near the site).
- Certain advance procurements that will be needed for the increased construction effort in FY 1991.

Schemes for installation of the technical systems, particularly the superconducting magnets, will continue to be refined in FY 1990. Detailed studies need to be made of the sequence of activities that must begin following beneficial occupancy of the enclosures and buildings at the site. A prototype magnet transporter should be acquired and tested.

Administrative systems must be developed and implemented to ensure that the machine configuration is controlled, quality is maintained, and a safe environment is provided for the work force.

The Detectors. To answer our questions about the structure of matter, the SSC must have a high collision rate. About 100 million proton-proton collisions will occur every second at the SSC, some of which will produce hundreds of particles. Identifying these evanescent products requires measuring their energies and directions.

To achieve this goal, many-layered will detectors surround the interaction region. Typically, closest to the collision point, a detector with good spatial resolution will track the many closely spaced particles emerging from the collision. Another layer will measure the curved paths that electrically charged particles follow in a magnetic field. The energy and direction of both charged and neutral particles or groups of closely spaced particles will be measured by the outer layers. In every layer, high spatial resolution will be important to distinguish different products.

Storing permanently the data from every collision would, of course, be impossible. Sophisticated electronics and computer systems will filter the data and discard phenomena that are already well understood, just as in daily life we pay closer attention to unusual occurrences than to the mundane. Only a handful of interesting collisions per second will be recorded permanently.

The SSC's high event rate, the large number of tracks per event, and the need to resolve the tracks of different particles with similar energy and direction present a challenge to detector technology. To meet this challenge, new detection and information-processing techniques must be developed or older methods improved.

Who Is Involved in SSC Detector R&D?

Universities

- Boston University
- California Institute of Technology
- Carnegie Mellon University
- University of Florida
- Florida State University
- Harvard University
- University of Hawaii
- University of Illinois
- University of Indiana
- University of Michigan
- University of Mississippi
- Northeastern University
- University of Notre Dame
- University of Oklahoma
- University of Oregon
- University of Pennsylvania
- University of Pittsburgh
- Princeton University
- Rockefeller University
- Stanford University
- State University of New York at Stony Brook
- University of Tennessee
- Texas A&M University
- UC Berkeley
- UC Davis
- UC San Diego
- UC Santa Cruz
- UCLA
- Yale University

Labs

- Argonne National Laboratory
- Brookhaven National Laboratory
- Fermi National Accelerator Laboratory
- Lawrence Berkeley Laboratory
- Oak Ridge National Laboratory
- Sandia National Laboratory
- Stanford Linear Accelerator Center

Detectors for the SSC must be very large to trap the very high energy particles that the SSC will create: an SSC detector might weigh as much as 50,000 tons and be as tall as a five-story building. Despite this enormous physical scale, research and development in the area of detector technology is carried out by small groups of physicists and engineers at universities and laboratories. Productive collaboration with industries involved in silicon detectors, advanced electronics and computing, scintillating materials, and many other areas is vital.

This year a broad and vigorous program of detector research and development is under way. This program involves twenty-nine universities and seven DOE laboratories, as shown in the accompanying table. In addition, substantial industrial cooperation and collaboration with university and laboratory researchers is taking place in the development of high-speed, two-dimensional silicon detectors, radiation-hardened VLSI electronic circuitry, and new scintillating materials, as well as sophisticated mechanical engineering studies of large detector subsystems and other areas. This generic research and development effort will improve the technological base for design of specific SSC experiments, which is anticipated to begin in FY90.

In FY90 a substantial increase in detector research and development effort and in experiment design activities will be required. Generic research and development on detector technology for the SSC must continue and increase in FY90. This work will continue to be done by small groups in universities and laboratories, working with industry where appropriate. In addition, significant new efforts must begin on the conceptual design of major subsystems of possible detectors, and preliminary work must be initiated on integrating these subsystems into an overall detector design. Fiscal Year 1990 is also the appropriate time to begin to form the large collaborations of physicists, engineers, and technicians that will design and construct the first SSC experiments.

Conclusion

To conclude, I would like to emphasize once more that SSC is a scientific instrument that has been endorsed as essential by the world-wide high-energy physics community. The work on research, development and design that has been performed during the last several years has defined the parameters of the machine, verified its technical feasibility and provided a bottoms-up cost estimate. In short, it gave us evidence that we are ready to go.

The selection of the SSC site and the M&O contractor gives tangible evidence of reality to this project. Together with the dedicated scientists and engineers who have devoted many years of work to this project, we are anxious to begin on this great intellectual adventure, that we believe will be an exciting and promising one. We seek your authorization of this project and look forward to that great moment eight or nine years from now when, with the help of this magnificent new instrument, we can begin to take new steps toward unlocking the secrets of our universe.

Madame Chairperson, this concludes my prepared testimony. I shall be happy to try to answer any questions that you may have.

Mrs. **Lloyd**. Thank you very much, Dr. Schwitters, and we are delighted to have you with us.

Professor Walecka.

STATEMENT OF PROFESSOR JOHN DIRK WALECKA, SCIENTIFIC DIRECTOR, CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY [CEBAF]

Professor **Walecka**. Thank you, Madam Chairman.

Hermann Grunder is suffering from the flu, and he has asked me to read his testimony which reports on the first two years of construction progress at the Continuous Electron Beam Accelerator Facility.

CEBAF is the highest priority nuclear physics project and the new basic research laboratories taking shape at the site. Our 267-member staff have use of laboratories and offices in two buildings and several trailers, and we are looking forward to the summer when we can occupy CEBAF Center.

Construction of the accelerator tunnel began last August and is on schedule. Nearly half of the excavation for the tunnel is done and work on the concrete accelerator enclosure is 20-percent complete.

Several of the accelerator systems being readied for use in the tunnel are already operating in our lab. We have successfully transferred to industry the technology of building the niobium superconducting cavities, and competitive bids to procure them in quantity are in the final stages of evaluation. Prototyping and testing of cryostats is complete. The first two-cavity cryostat for the injector is being assembled, and the first eight-cavity module is being prepared for tests in June.

Our source of electrons has been operational for over a year. The electron source in cryostat tests are controlled by the accelerator's computer control system, which has achieved acclaim and is being adopted by other laboratories.

These early hardware tests, along with computer modeling of beam behavior, are part of our strategy to anticipate and solve the challenges of startup and initial operation. I expect them to pay dividends later in terms of smooth commissioning of the entire facility.

Meanwhile, the nuclear physics community is working closely with us to plan both the research program and the equipment needed for CEBAF's experiments. Some 233 physicists from 58 institutions sent us 90 letters of intent describing physics experiments they are interested in performing at CEBAF. With the community we have completed the preliminary conceptual designs for the large and complex spectrometers and detectors and have finalized the conceptual designs of the three buildings to house the experiments.

Just two weeks ago, CEBAF's Program Advisory Committee held a pivotal meeting to review the letters of intent and the preliminary equipment design. They concluded that the experiments and equipment constitute three complementary programs of excellent physics research.

Our attention is turning now to planning the experiments in detail, finalizing the designs, and building the equipment. Our next step is to call for formal proposals for the initial set of experiments to utilize the three simultaneous beams.

Collaborations involving scientists from universities and other laboratories will need to provide about half of the manpower to design and build spectrometers and detectors. This effort thus represents a significant opportunity for universities to strengthen their on-campus nuclear physics activities.

We are pleased that the President's budget for fiscal year 1990 requests $65 million for CEBAF construction and treats the nuclear physics program overall very responsibly. Also important is DOE's fiscal year 1990 guidance for CEBAF's nonconstruction funds, totaling $19.1 million, to support R&D, preoperations, and administration.

Congressional appropriation of the administration request would keep CEBAF on schedule for completion in the fourth quarter of fiscal year 1993.

It has been rewarding for me to see how our efforts at CEBAF have contributed to industry and education. We have provided a technological boost to industry, not only in the arena of superconducting cavities but also in other areas where our components demand the state of the art.

We find ourselves to be a resource for education at all levels and to be stimulated in turn by bright young people; from graduate students participating in courses offered at CEBAF to high school and college students working at CEBAF; from elementary and secondary school teachers and students who tour CEBAF or invite our staff into their classrooms to community groups and leaders who follow our progress with pride.

The City of Newport News and the Commonwealth of Virginia still believe their investment in CEBAF to be sound. All together, their contributions total some nearly $14 million, including the site and office building, some staff, and a guest home for visitors.

International interest in our scientific program is growing now that construction is advanced. Physicists from Europe and the Orient approach us eager to collaborate on the scientific program. Discussions regarding the details are underway.

I want to close by thanking this subcommittee, the Congress and the Department of Energy for guidance and support. Please come to Newport News to see for yourselves the excitement and progress at CEBAF.

Thank you.

[The complete prepared statement of Dr. Walecka follows:]

Written Testimony of Dr. Hermann A. Grunder, Director,
Continuous Electron Beam Accelerator Facility
before the
Committee on Science, Space, and Technology
Subcommittee on Energy Research and Development
February 23, 1989

Introduction

I am honored to come before you today to report on the progress of the Continuous Electron Beam Accelerator Facility and to discuss CEBAF's role in the advance of science, technology, and related education in our country.

CEBAF's goal is a new understanding of the atom's nucleus, and thus a new understanding of the nature and structure of matter itself. This new understanding will help build the knowledge base for future technologies. With construction well under way, and with the nation's nuclear physics community engaged in preparing for the research opportunities the accelerator will offer, there is much to report about our progress toward this goal.

Construction of the accelerator tunnel began last August and is on schedule. Nearly half of the excavation is done, and work on the concrete accelerator enclosure is 70% complete. Several of the accelerator systems being readied for use in this tunnel are already operating on a small scale in our test lab. One—the computer-based accelerator control system developed at CEBAF—is being adopted by other laboratories.

The test lab, inherited from an earlier NASA laboratory, has been refurbished as an up-to-date, multipurpose center for accelerator component work. A key element of this work will soon be the assembling of industrially produced superconducting accelerating cavities into cryostats for use in the accelerator. We have successfully completed both prototyping and laboratory-to-industry technology transfer for cavities, and we are now procuring cavities in quantity.

Meanwhile, the nuclear physics community is involved in planning both the research program and the complex equipment needed for CEBAF's experiments. Some 233 physicists from 58 institutions have recently submitted 90 "letters of intent" describing physics experiments they are interested in performing at CEBAF. CEBAF and members of the physics community have completed the preliminary conceptual designs for the large and complex spectrometers and detectors to be used in experiments, and have finalized the conceptual civil construction designs of the three buildings to house the experiments. Our next step in scientific planning is to call for formal proposals in March, so that the initial set of experiments to utilize the three simultaneous beams can be selected this fall.

In this testimony I first report to you the details of accelerator and scientific program progress, and then describe CEBAF's place in the national and international context.

Construction Progress

The accelerator's job will be to send a continuous beam of high-energy electrons to nuclear physics experiments in the three experiment buildings (Figure 1). Electrons are ideal probes of the atom's nucleus. CEBAF's combination of beam characteristics—energy, intensity, and duty factor—will enable these probes to be used in a new way to reveal clear, detailed views of the nucleus.

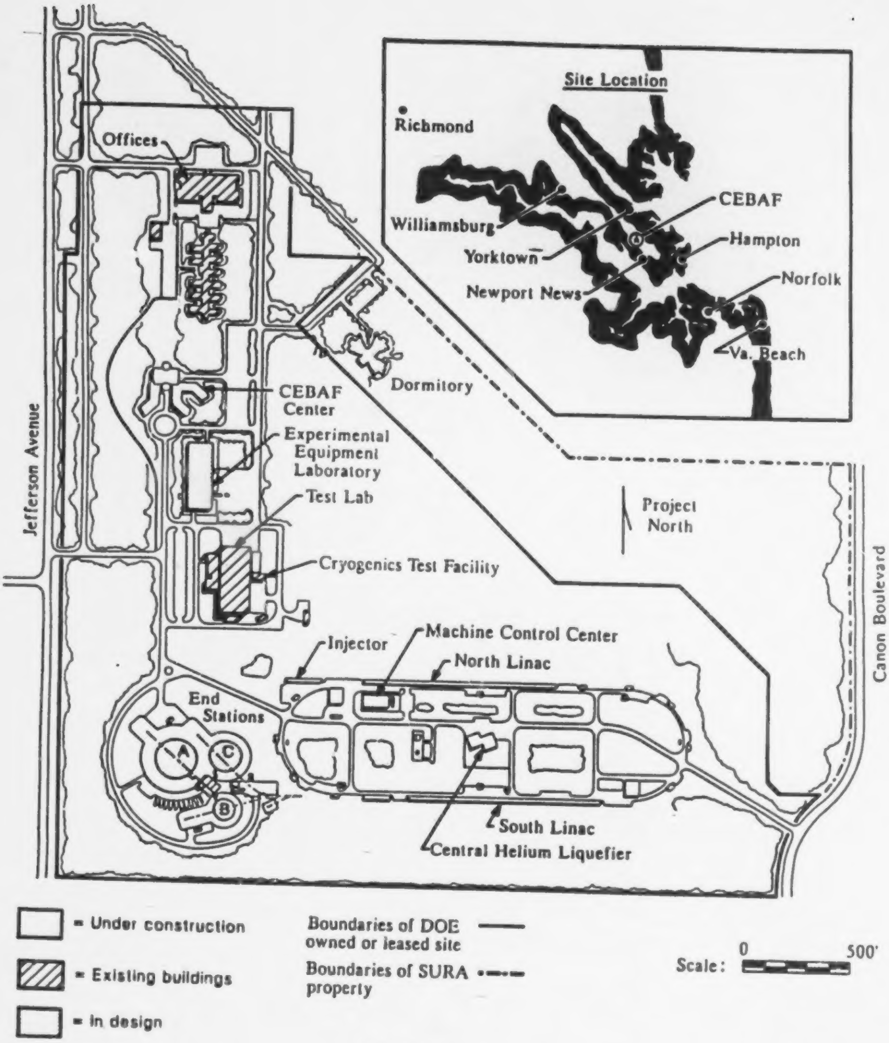
To produce the needed beam of electrons, CEBAF will use two linear accelerator segments, one inside each straightaway of the racetrack-shaped accelerator tunnel—7/8 mile around and 26 feet underground. Excavation for one of the straightaways and one of the racetrack's arcs is near completion, and the concrete accelerator enclosure in those sections is being built. The enclosure for the injector, the region of the accelerator where the beam originates, is complete (Figure 2). The tunnel is on schedule for completion in May 1990. The contractor for the $19.7 million tunnel construction project is Caddell Construction Company of Montgomery, Alabama.

This summer, when the tunnel builders move on to other parts of the racetrack, accelerator scientists and engineers will begin to set up and operate the injector and initial sections of the accelerator in the tunnel now being completed. Preparations for this testing of the accelerator's "front end" are under way in the test lab. The electron source has been operational for over a year, and has successfully achieved the needed quality of the electron beam. These tests are controlled by major elements of the accelerator's computer-based control system. The control system is also in use for tests of other accelerator systems. I expect that this early use under realistic conditions will pay dividends later in terms of smooth commissioning of the entire facility.

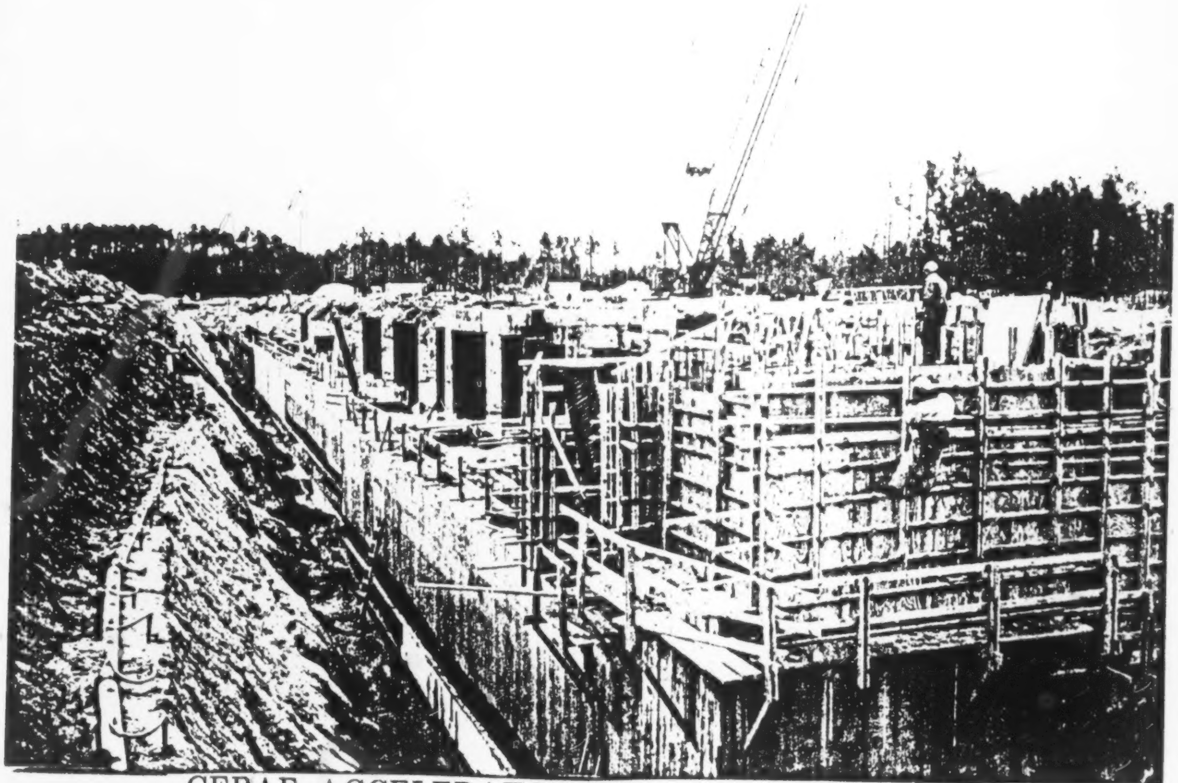
At CEBAF we consider the control system to be a major accomplishment. Its technical features define the present state of the art, and it has been adopted by Lawrence Livermore National Laboratory, Yale University, and MIT-Bates Laboratory. The system is under serious consideration for accelerators at other major laboratories.

We have successfully transferred to industry the technology of building the niobium superconducting accelerating cavities (Figure 3), and competitive bids from industry to produce the cavities in quantity are in the final stages of evaluation. Some 360 of these devices are being purchased. Prototyping and testing of cryostats—the liquid-helium containers that keep the cavities at their superconducting operating temperature near absolute zero—is complete. The first two-cavity cryostat (Figure 4) for the injector is being assembled, and the first 30-foot-long, eight-cavity module made of four such cryostats is being prepared for tests this June.

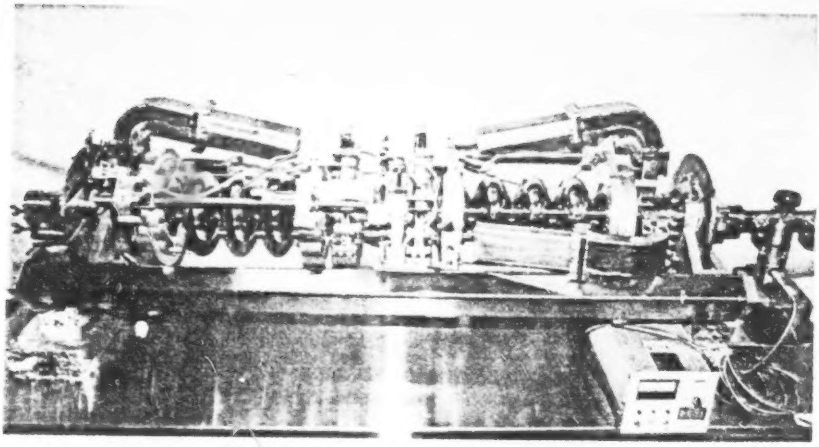
Cavity and cryostat testing is now supported by an on-site plant that produces liquid helium at the required 2 Kelvin (−456° Fahrenheit). The accelerator itself will use an $8.5 million central helium liquefier now under construction at CVI, Inc., of Columbus, Ohio. This will be the world's largest such plant for producing liquid helium at CEBAF's operating temperature. Construction of the liquefier and of the building to house it at the center of the accelerator ring are on track for initial operation in late 1990.


Site Location
Richmond
Williamsburg
Yorktown
Newport News
CEBAF
Hampton
Norfolk
Va. Beach
Offices
Dormitory
CEBAF Center
Experimental Equipment Laboratory
Test Lab
Cryogenics Test Facility
Jefferson Avenue
Project North
Canon Boulevard
Injector
Machine Control Center
North Linac
End Stations
A
B
C
South Linac
Central Helium Liquefier
= Under construction
= Existing buildings
= In design
Boundaries of DOE owned or leased site
Boundaries of SURA property
Scale:
0
500'

CEBAF Site Plan
Figure 1

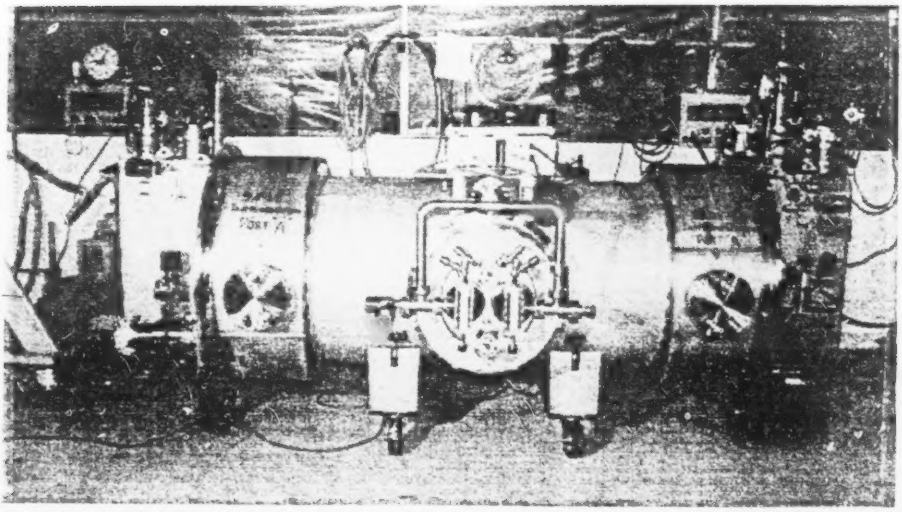


CEBAF ACCELERATOR TUNNEL CONSTRUCTION
FEBRUARY 1989
(Figure 2)



Superconducting Cavity Pair

Figure 3



CEBAF Cryounit

Figure 4

Other accelerator component efforts include work on room-temperature magnets that will steer the beam, on beam monitoring devices for use with the accelerator control system, and on the radio-frequency systems that provide power for acceleration. Permanent facilities for accelerator component assembly and testing have been installed and are coming on line.

In parallel with component test and assembly work, accelerator physicists are planning the commissioning of the accelerator. By modeling accelerator component performance and beam behavior using DOE supercomputers, they are anticipating and solving several challenges of startup and initial operation.

CEBAF Center—to provide offices, an auditorium, a computer center, conference rooms, and a cafeteria—is 60% complete, and on schedule for occupancy by early fall. Armada/Hoffler, Inc., of Chesapeake, Virginia, is contractor for the $5.5 million building.

Scientific Program Progress

CEBAF is being built as a user facility available to national and international experimental physicists. As predicted by the Bromley Panel in its 1983 review of proposals for a continuous beam electron accelerator, "a substantial effort—involving all prospective users of these facilities—will be required to determine the optimum mix and design of the experiment facilities. [Especially] crucial is the early formation of a strong user group to involve the national nuclear physics community in the design and construction of this equipment."[1]

The partnership between CEBAF and the physics community continues to grow. The CEBAF User Group now has 676 members representing over 200 universities and scientific institutions in 37 states and several countries. The past year has seen significant progress in experimental program and equipment planning, with 18 formal collaboration meetings and the receipt of 90 letters of intent detailing specific experiments from 233 physicists at 58 institutions. In December we completed the preliminary conceptual designs of the spectrometers and detectors to be installed in the three experiment buildings to support the experiments.

Just two weeks ago, CEBAF's Program Advisory Committee—an international panel of prominent nuclear physicists—in its pivotal meeting to outline CEBAF's experimental opportunities, reviewed the letters of intent and the preliminary equipment designs. After the three-day review, the committee concluded that the experiments and equipment proposed constitute three exciting, mutually complementary programs of excellent physics research, appropriate to the investment in CEBAF. We know now that the physics at CEBAF is even more exciting than anticipated when the facility was first proposed.

With this endorsement, our attention is turning to planning and prioritizing the experiments in detail, finalizing the designs, and building the equipment. We will call for formal physics proposals immediately to define the initial experimental program by the fall. In parallel we are forming equipment collaborations charged to develop final equipment designs to accomplish the proposed research. The proposals and the designs will be reviewed by the Program Advisory Committee late this year. DOE approval of the equipment plan will be an important step before construction of the equipment can begin.

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[1] "Report of the Panel on Electron Accelerator Facilities," DOE/NSF Nuclear Science Advisory Committee, DOE/ER-0164 (April 1983), page 67.

Already this year, three collaboration meetings have been held—one for each hall—focusing specifically on the experimental interests, roles, responsiblities, and commitments of the user/collaborators from universities and other research institutions. As anticipated by the Bromley Panel, strong participation by these individuals will assure that the experimental equipment matches the experimental program. We estimate that the effort of the universities and other institutions—including faculty, post-doctoral fellows, graduate students, undergraduates, and others—to design and build specific spectrometer and detector components to install at CEBAF will amount to roughly 60 FTE/year, starting in FY 1990. The universities will need to secure significant additional equipment funds to support their equipment development and supplement the effort at CEBAF.

Funding

The $49.7 million of construction funds appropriated by Congress for FY 1987 and FY 1988 have been obligated. Through January 1989, we have committed 58% of the $44.5 million appropriated for FY 1989. The $25.9 million committed through January 1989 has been spent on subcontracts with industry ($13.3 million or 55% directly or indirectly to small business). The President's Budget for FY 1990 requests $65 million for construction, identical to the projection of a year ago. The Budget Request is generally consistent with DOE's guidance of funding for R&D, preoperations activities, and laboratory administrative support, estimated at $19.1 million in FY 1990. Congressional appropriation of the Administration request would keep the project on schedule for completion in the fourth quarter of FY 1993, at no increase in cost.

With the requested FY 1990 appropriation, we will complete tunnel construction, procure major quantities of key hardware components (cavities, cryostats, magnets, and klystrons), begin procurement of experimental equipment components and prepare an area for their assembly and testing, and start construction of the end stations.

I would like to note that overall, the budget request appears to be at a responsible level to support the nation's nuclear physics program. While promoting the vitality of the base program, this budget allows CEBAF to stay on course, it prepares the base for the Relativistic Heavy Ion Collider (RHIC), and it enables universities to support the vital activities of scientists and students preparing for the exciting research opportunities at CEBAF.

CEBAF in the National and International Context

Scientifically, CEBAF complements other forefront projects designed to advance the frontiers of knowledge. CEBAF's field of study is the quark structure of the nuclei of atoms. The proposed Superconducting Super Collider (Texas) will study the quarks themselves; the Relativistic Heavy Ion Collider planned at Brookhaven National Laboratory (New York) would study nuclear matter under extreme conditions—the quark-gluon plasma. Taken together, these facilities comprise an arsenal of new tools for expanding our knowledge of matter.

Whereas CEBAF's primary purpose is basic research to deepen our understanding of matter, this effort intrinsically builds the knowledge base for future technologies, and it has tangible benefits in the near term. CEBAF's specific near-term contributions stimulate technology and industry by

- helping advance the state of superconducting radio-frequency technology,
- commercializing superconducting accelerating cavities,
- improving the state of the art in computer technologies, such as control systems, data-acquisition, and data-analysis techniques, and
- challenging industry to produce other CEBAF components.

Another major benefit of a project like CEBAF is in education. Forefront facilities and their scientific and technical opportunities inspire young scientists and engineers and contribute to the intellectual stimulation of students at all levels. CEBAF's experimental equipment development thus represents a significant opportunity for universities to strengthen their on-campus nuclear physics activities by participating in designing and building the equipment, in addition to performing experiments at CEBAF. Although operation of CEBAF for physics research is nearly five years away, some of CEBAF's links with education are already emerging:

- Graduate courses are taught by our Scientific Director and attended by students from area universities.
- The summer program, Hampton University Graduate Studies at CEBAF, is entering its fourth year of bringing graduate students from across the nation to CEBAF.
- Graduate students and post-doctoral researchers participate in our scientific program planning and will shortly become heavily involved in building experimental equipment.
- Several of our senior scientific staff have academic ties to regional universities.
- Numerous student and faculty groups tour CEBAF, like the Virginia Association of Science Teachers scheduled to come this April during their annual convention.
- CEBAF provides mentorship opportunities for high school and college students.
- CEBAF scientists conduct programs in schools (elementary through college).

The value of these benefits to technology, science, and related education is appreciated and understood by the local and regional communities. The city of Newport News, for instance, has supported CEBAF from the beginning, providing land for the laboratory ($3.2 million) and funds ($692 thousand) for a guest house to be constructed this year for visiting experimenters. The Commonwealth of Virginia funds Governor's Distinguished CEBAF Professors and Scientists who work at CEBAF and simultaneously hold affiliations with Virginia universities, and provides administrative personnel, land, and facilities (equivalent to approximately $2 million per year). CEBAF's sponsoring consortium of 39 universities and colleges, the Southeastern Universities Research Association, not only provides the framework for connecting CEBAF with the nation's universities, but its member universities participate actively in the collaborative efforts to prepare CEBAF's program of nuclear science. In fact, 68 of the 90 letters of intent to perform specific experiments involve 64 physicists at 16 SURA universities. Twenty-four of thirty new faculty positions in nuclear physics pledged by SURA universities have been estalished

Internationally CEBAF is receiving considerable attention both scientifically and technologically. European and Japanese physicists are participating strongly in scientific program development. Both in Italy and Japan workshops on CEBAF-inspired physics are attracting wide attention. A formal agreement for collaboration with the Italian nuclear physics institute (Instituto Nazionale di Fisica Nucleare, INFN) is to be signed in May when its president, Professor Nicola Cabibbo, visits CEBAF. France has interests both in

CEBAF's superconducting cavity technology and in the experimental program. A complementary CEBAF-type machine has been proposed to be built in Saclay (near Paris), and the construction decision is expected in summer 1989. Discussion of a collaboration to build large superconducting quadrupoles for CEBAF's spectrometers is under way with Saclay.

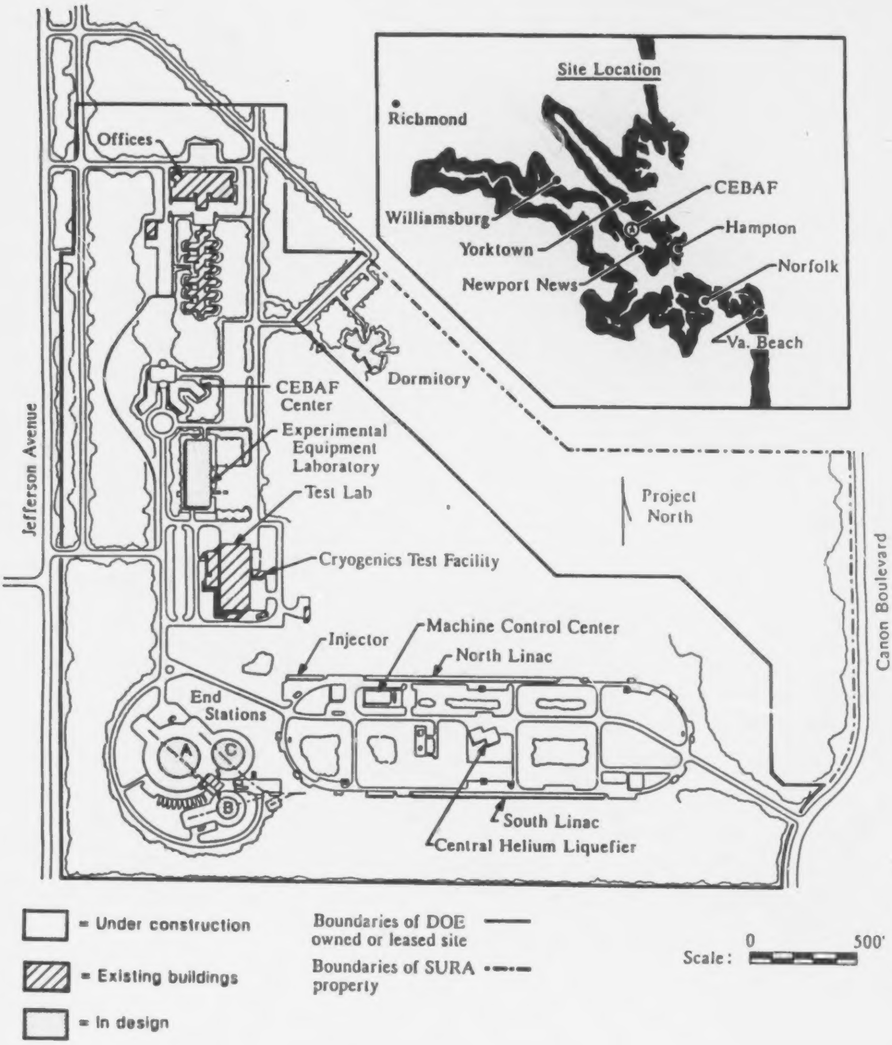
CEBAF is a growing, successful project and research laboratory with a capable, committed staff and enthusiastic support in the region, in the nation, and throughout the world. We appreciate the guidance and support of DOE and Congress, and we take seriously our role as America's highest-priority nuclear physics project.

Let me close by inviting you to come to Newport News to see and feel the excitement of building this world-class facility. Thank you again for your support of our efforts.

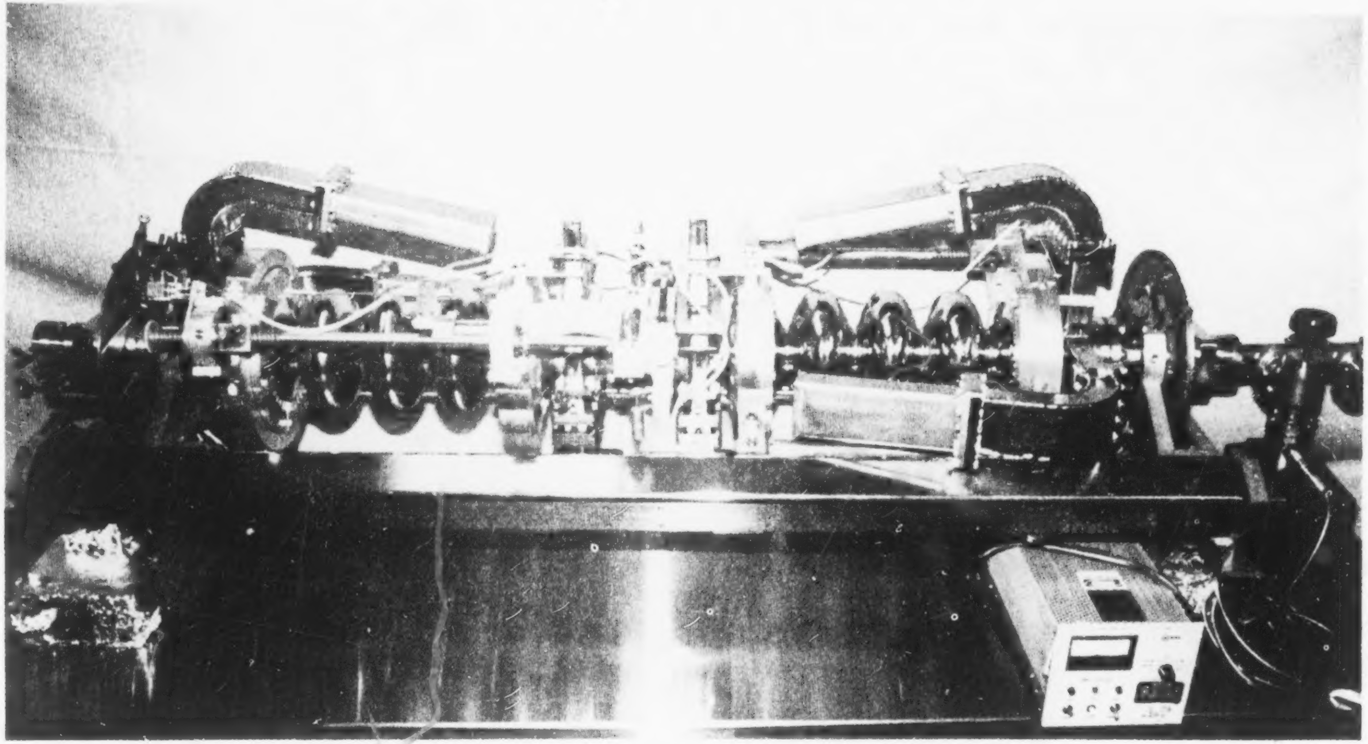
Congressional Testimony Photographs

Photo #1	CEBAF Site Plan
Photo #2	CEBAF Accelerator Tunnel Construction/February 1989
Photo #3	Superconducting Cavity Pair
Photo #4	CEBAF Cryounit
Photo #5	CEBAF Accelerator Tunnel Construction/February 1989
Photo #6	CEBAF Computer Control Console
Photo #7	End Station A

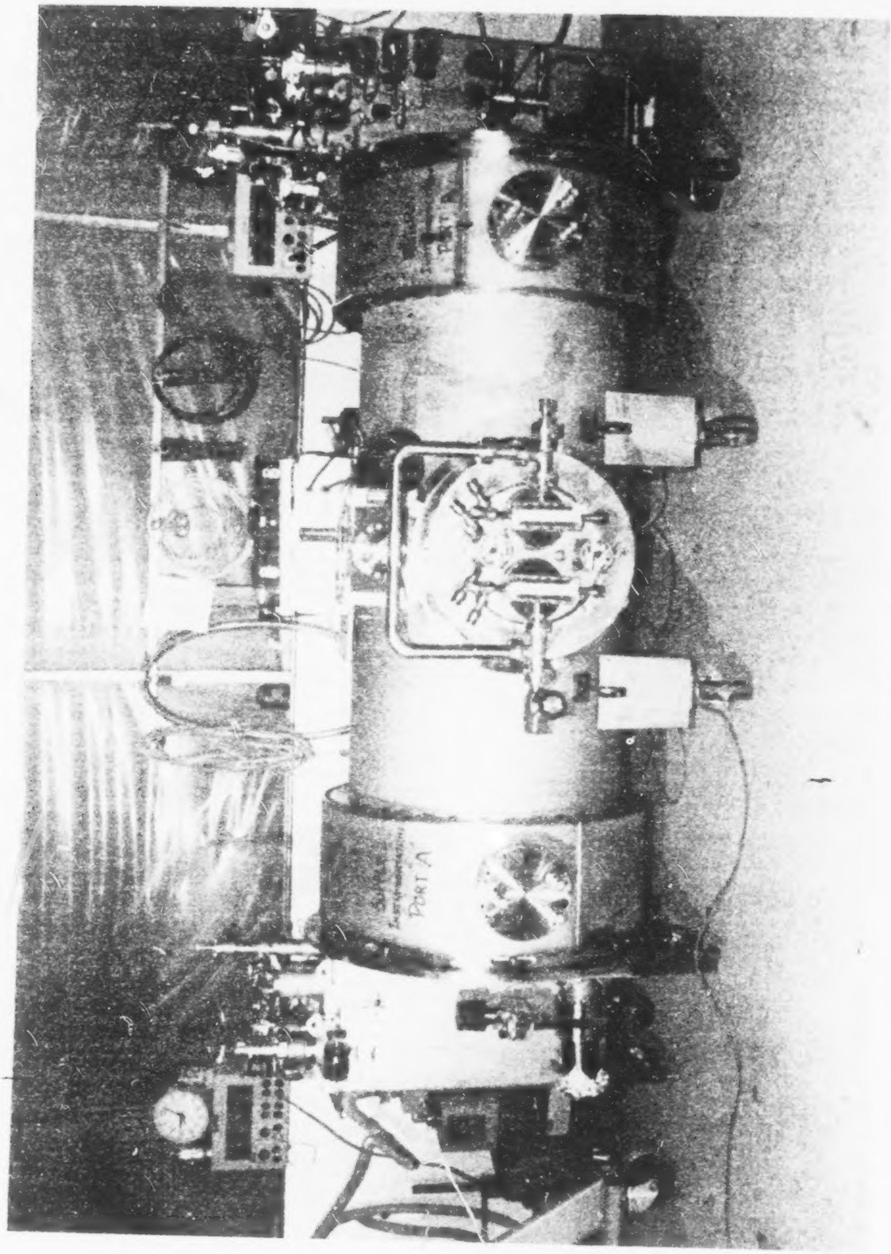
SITE PLAN CEBAF


Site Location
Richmond
CEBAF
Williamsburg
Hampton
Yorktown
Norfolk
Newport News
Va. Beach
Offices
Dormitory
CEBAF Center
Experimental Equipment Laboratory
Test Lab
Project North
Jefferson Avenue
Canon Boulevard
Cryogenics Test Facility
Machine Control Center
Injector
North Linac
End Stations
A
C
B
South Linac
Central Helium Liquefier
☐ = Under construction
▨ = Existing buildings
☐ = In design
Boundaries of DOE owned or leased site
Boundaries of SURA property
Scale: 0 500'

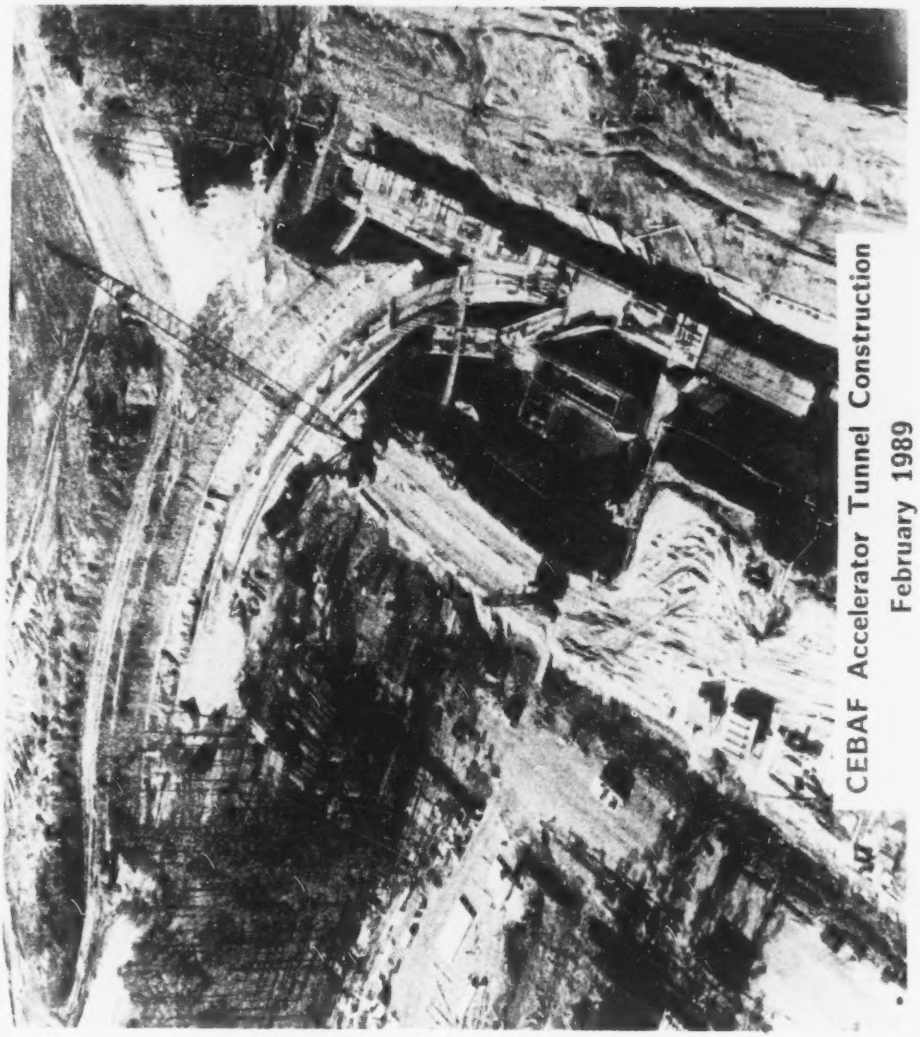
CEBAF Accelerator Tunnel Construction
February 1989



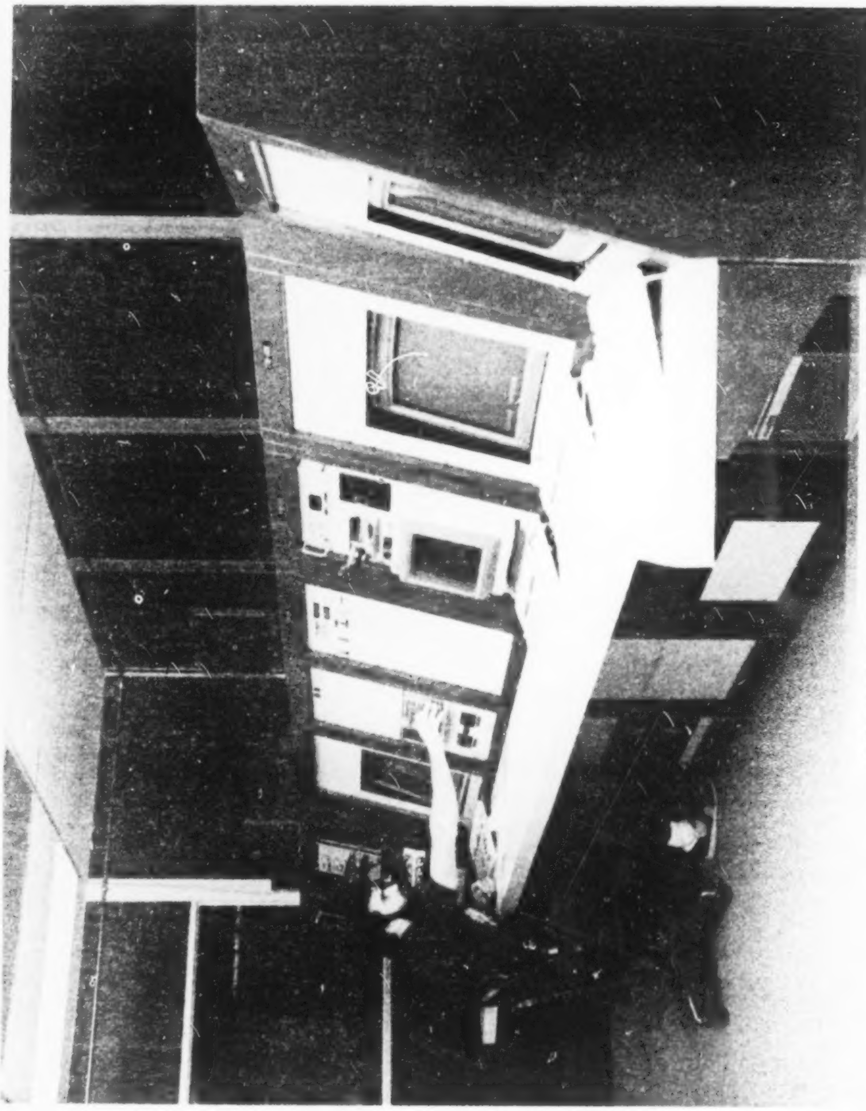
Superconducting Cavity Pair



CEBAF Cryounit



CEBAF Accelerator Tunnel Construction
February 1989

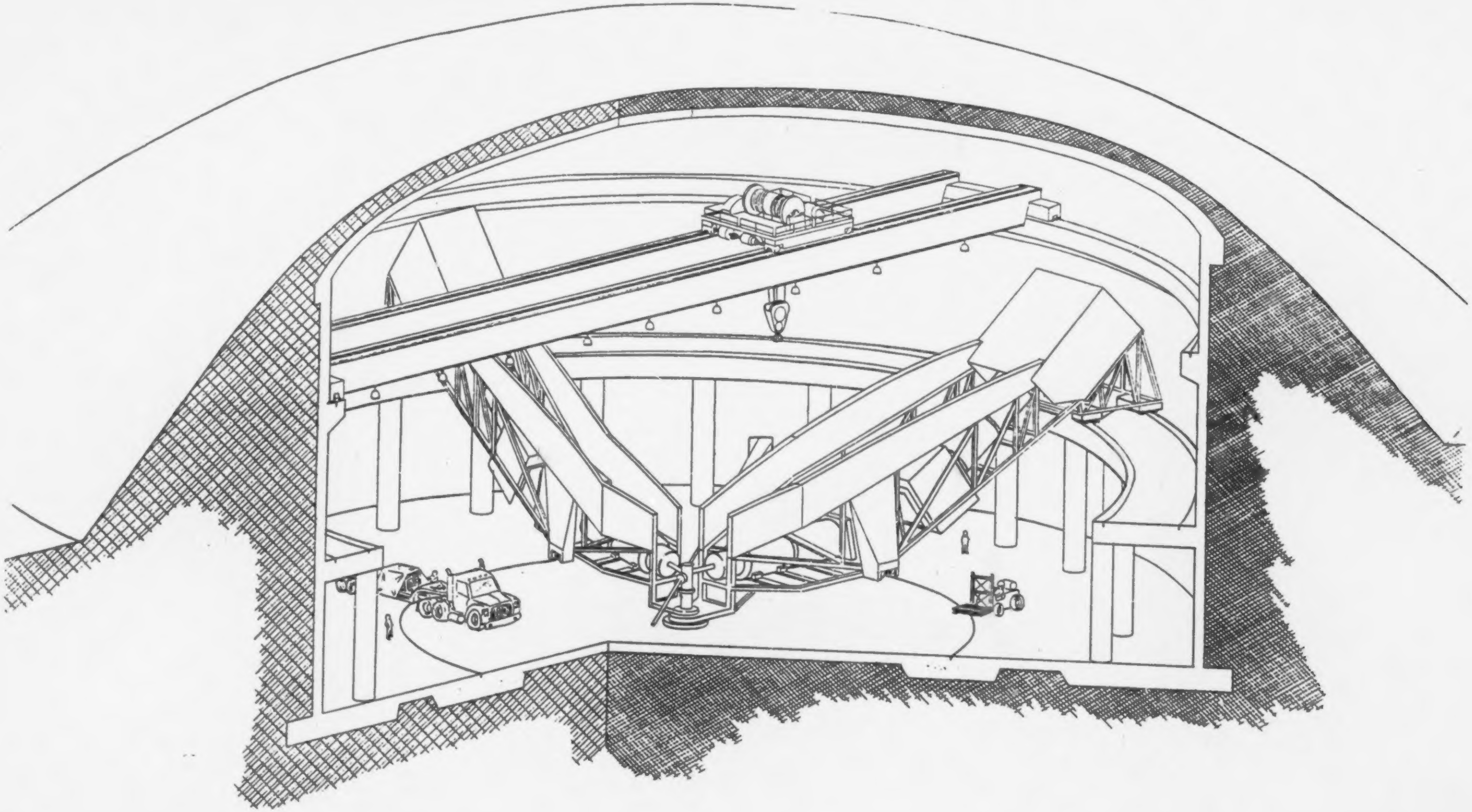


CEBAF Computer Control Console

END STATION A

CEBAF

High Resolution Spectrometers



PANEL 1 DISCUSSION

Mrs. **Lloyd**. Thank you, Professor Walecka, and I am looking forward to visiting you at CEBAF and seeing your progress as well.

To all of you distinguished panelists, I would like to pose the question that we as members of this committee are faced with budget realities, and I would like to ask you if you are willing to accept the possibility that the SSC may be paid for by significant reductions in other high energy physics programs. We certainly want your reaction to this dilemma that we may be facing.

Dr. Richter, if you will start.

Dr. **Richter**. You certainly start off with the toughest question first.

It is a dilemma. The problem is if one builds the SSC one is going to have the tool with which to do research that will turn on at the end of the 1990s. Between now and the end of the 1990s all the high energy physics that we do in the U.S. is going to be done at the laboratories which already exist. If we don't support those programs well, we are not going to have any high energy physics program.

The thing that attracts students to high energy physics, the thing that attracts young researchers is simply the opportunity to do research, and so, yes, indeed, there is a real dilemma here. We must keep opportunities for advanced research on the frontiers of high energy physics alive during the time of construction of the SSC, and if we don't do that, we are not going to have the people to use them except those people who will come from overseas to use the SSC.

So I would say that I don't know what we will do in response to the budget cutbacks in the base program, but if it is cut back significantly, we are not going to have much high energy physics to play with and I really don't think you should.

Mrs. **Lloyd**. Thank you.

Dr. Lederman.

Dr. **Lederman**. I usually agree with everything Burt says. I think I would certainly echo that and tried to indicate that in our testimony.

You know, a graduate student can't join the SSC now and get his PhD at the end of the 1990s. It just wouldn't work, and he has got to have a place where he can do research in a shorter term point of view, and that is also true of post-docs on the first step of their career, and for that he needs working accelerators.

Mrs. **Lloyd**. Dr. Schwitters.

Dr. **Schwitters**. I basically agree with what Burt and Leon have both said. We are certainly exploring ways where—and we will be doing programs—where the students and young post-docs will be working on advanced parts of the SSC during construction, but they also have to do physics research in that period.

On the other hand, as you well know, this is a long project, and that gives a lot of us a great deal of concern, and in order to get on with it in the most effective, cost effective and just vital way, we need to give it a very, very big commitment and shot in the arm right now.

Mrs. **Lloyd**. Professor Walecka.

Professor WALECKA. I agree with the statement that Dr. Lederman made at the beginning of his testimony. I think that basic research is one of the best investments this country can make, and I think the SSC is a large enough project that it really has to be kept separate. It can't be paid for out of the existing basic research programs.

Mrs. LLOYD. Dr. Schwitters, it has come to the attention of this Committee—I would like your comments on it—that the complement of the high energy physics personnel—that is the research, the management, and the accelerator people—is rather limited. Is your staff going to draw on the ongoing programs at SLAC and Fermi and elsewhere?

Dr. SCHWITTERS. Of course, we have to draw on some of those people, but we are very aware of this vital resource of these people, and as I just mentioned, we are also concerned that a strong program go on in those areas.

So for that reason at the beginning we are stressing the need to involve industry in many areas that have traditionally been covered by the—if you will, the scientific academic side. That will take place in the beginning of the program.

We will also continue programs cooperation with SLAC, Brookhaven, Fermilab, and so on, where it is in our common interest to do so, as we are now, the magnet R&D, injector systems, and so forth.

Ultimately—well, let me say one more point. We are exploring new ways to work with the academic community. We will be drawing on visiting professors. There is a lot of opportunity opening up among a number of universities who have taken the challenge of the SSC and are actually developing more groups and opportunities for academic appointments in that area.

Ultimately, of course, when we are completing the construction phase and go into operations, many of the scientists will move over from the current laboratories because they simply want to be where the action is, and so it is inevitable, as we have traditionally in the past, that those scientists will move over when it is in their scientific interest to do so and work on this.

Mrs. LLOYD. To the best show in town?

Dr. SCHWITTERS. That is right.

Mrs. LLOYD. One final question, Dr. Lederman, that is not really related to this. I would like to touch on, if I may, just with your indulgence. I will shorten up later on.

But we have had several conversations on the role of education to attract more young people into our science careers and programs. At the same time we know that we aren't putting the money into civilian R&D that is going for our defense research and that our friends of the Pacific rim and our European friends as well aren't spending the money on defense dollars as we are.

If we are really going to attract new wealth for this country, would you like to comment on the direction you feel that we have got to go in to attracting more young people for the record?

Dr. LEDERMAN. Well, I think the statement is correct. If you look at the trends in basic research, nonmilitary basic research, it has not been growing nearly as fast as our economic competitors in Western Europe and in Japan, where civilian R&D as normalized to the Gross National Product considerably has trends which are *quite up and the U.S. trends are down. I think that is alarming,* and I think that it is connected. I think underlying everything we do is education here and science education, and without improving on those elements dramatically, I think, the SSC and the Fermilab and the SLAC programs and even the efforts to use the additional funds will be wasted.

So I think it behooves all of us, both from the point of Washington but from the point of view of the country, to initiate all kinds of activities of the kind Fermilab has been doing with third graders and fourth graders and high school teachers, and so on, to try to reinvigorate the educational process in the country.

Mrs. LLOYD. Thank you very much.

Mr. Morrison.

Mr. MORRISON. Dr. Schwitters, some of the detractors of the super collider say that it will be made obsolete because of some of the new superconducting materials, and I would like to have the latest version of the arguments we use against them.

Dr. SCHWITTERS. OK. There's actually a lot known about those materials now, and the new materials really don't have the kind of properties we need in these magnets. Specifically, we are looking for high current carrying capability, the so-called critical current, essentially the amount of current you can stuff through a wire without it burning up or going normal.

New materials are not particularly strong in that area compared with the developments in the so-called old materials. I must say I think it does the materials science community a disservice to claim that the "old" materials are not themselves interesting because they have made really dramatic improvements.

Anyway, that is one reason. We need to carry as much current as possible through the magnet. That forces us to the old materials.

The second point is just the normal—the properties of the materials are such that the new things are rather brittle and difficult to form into wires that you can bend around into the shape of a magnet.

And finally—and this was an interesting point—is that around this machine you need an extremely good vacuum for the beams to circulate in inside the beam pipe. If you have gas molecules in there, the beams will collide and scatter out, and so on, and cause problems.

Now, it turns out that the most cost effective way to provide that vacuum is with a very low temperature cryogenic system; that is, the liquid helium system that is also appropriate for the materials that we are using.

So we have made a deep investigation into that question and are confident that this is the way to proceed.

Mr. MORRISON. Thank you. Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much.

Mr. Fawell.

Mr. FAWELL. Thank you, Madam Chairman.

Dr. Lederman, I read your statement in full, and as usual you have a unique way of expressing yourself and I think make your points very clear.

I noticed you made the statement when you were talking about that much depends upon two elements, the reasonable operating budget as in fact given in the fiscal year '90 budget and the increments of continuous improvements, and you are in the unique position of really fully concurring that the budget looks good and not having to complain, nor are you complaining about it.

But you do understandably go on to say that if Congress follows its past procedures or actions that there might be some cuts expected, and in your statement, your oral statement, you said you are uncertain—you feel uncertain about the future. You are a bit stronger in your statement. You said I am terrified that we may fail to exploit this scientific instrument.

So a clarification in the written of being terrified in the written statement. You have somewhat modified and cooled a bit in your oral statement, and I can understand that, and yet the feelings I think, as Madam Chairman has expressed—I think her question was the SSC may be paid for by the reduction in other high energy physics programs. I think probably there are a number on this subcommittee that are looking at other programs, too, and saying that though you may in the presentation of the budget put the SSC off in a separate category it just isn't possible to be in that separate category because the money isn't in separate categories.

So that you do have this—I think I could quote Dr. Cronin at the University of Chicago, and I think Representative Barton did make reference to him, when he said that we are perhaps spreading our high energy physics talent too much as well as our available funds too much, and I will go back to saying that a lot of people think that in terms of other areas of small science that may be the case.

I don't know, the dilemma is ours. I don't know what you do about that.

Does anybody have any answers to that?

Dr. LEDERMAN. I feel I should answer, but I am not sure I heard the question.

Mr. FAWELL. Well, it may have been more of a speech than a question, I guess.

Dr. LEDERMAN. But it was a good speech. I liked it.

All I can say is I alternate——

Mr. FAWELL. Are we spreading our high energy physics talent too much?

Dr. LEDERMAN [continuing]. Oh, no. Yes, that is a problem. That is a good problem. I don't really think so. I think in the high energy physics business we have thought in some detail about the flow of people, both—there are two types, the accelerator types and the user types, the people who use the—who do the research, and there is an overlap, but there's also two different communities.

I think in both communities, as you watch the flow of people, you find, I think, that you can solve the problem. You demand the good qualities of the present machines right through SSC turn on. There will be a flow of people gradually from the existing activities to the SSC, increasing rapidly as you get to T minus say a year or two, because that is when the young people can start going over. And if you look at that flow and look at the charts and you realize that Europeans and Asians and South Americans, and so on, will be using this machine, I don't have any problems there.

And as far as the accelerator experts, this of course—accelerators are something that high energy physics founded, but if you go to an accelerator conference nowadays, you find only about 20 percent of the people there are high energy physicists because the accelerator arts are spreading everywhere—medical accelerators, industrial accelerators, nuclear accelerators, and so on.

So the community from which Roy will have to draw outside of Fermilab is very large.

Mr. **Fawell**. That may not be an exception.

Thank you. It is an impossible question, I guess, that I have posed. Unless anybody else wants to tackle it, I will say thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much.

Mr. Schiff.

Mr. **Schiff**. Thank you, Madam Chair.

I would like to echo what I believe I have heard in different ways from my colleagues here. I understand the point of view that there is great support for the SSC, that it would be a next step in terms of what we have now in accelerator physics, high energy physics.

I also understand the argument that, well, we can't do nothing in high energy physics until the SSC comes online because that is too many years and we will lose too much time that it could be put to good use.

I kind of wonder, though, if the high energy physics community, leaders such as yourselves, are working together in terms of timetables of the various projects that are proposed to us. In other words, there is construction going on now on other accelerators. There are proposals I think we are going to hear about today for advancement and increases in existing accelerators.

I wonder if there is a community of thought and planning as to the economic efficiency of what is being proposed now versus the time when SSC comes on because my concern is frankly authorizing projects which will become obsolete in terms of their usefulness when the SSC comes on. So I wonder if there is advice to us and we have a plan, we can use this and it will be valuable and cost effective for a certain number of years until we have SSC or if, frankly, there are simply individual project proposals without regard to SSC and anything else.

Dr. **Lederman**. I think that high energy physics is probably one of the most planned activities that I know of, and in many ways we have been held up as an example for many, many other fields. We have had in place since the '60s something called the High Energy Physics Advisory Panel, HEPAP, which is a representative of the community and which just agonizes over these plans over and over again.

And I think—so that the answer to your question is there is certainly a lot of planning on this thing, and that is why we started thinking about the SSC in 1983 for a project that probably wouldn't come on until 1997 or 1998. So there is a very long range thinking on this.

Fermilab itself came on in 1972, and the gleam in the eye was 1963, when again a HEPAP sort of considerations and planning, and HEPAP does think about both the ongoing physics and the new facilities that have to come on in the future.

So I do think there is planning, and I do think that most of the things that are on the table between the improvement of existing facilities and the onset of SSC could be contained within a budget which for high energy physics outside of SSC is considered to be more or less keeping up with inflation and with the SSC on a rapid, hopefully, funding profile and as it goes down maybe there will be some brilliant ideas for something brand new or maybe the SSC will be so promising that it will tell us how the universe works and we won't need anything after that. We will go away and not bother you.

But not very likely.

Mr. SCHIFF. I was just going to say that would be a first, I think.

One other question, Madam Chair, if I may.

Do these other—I think I have explained my concern to you—do these other projects that may be coming before us to expand the usage of present accelerators, have they gone through the—I believe you call it—the High Energy Physics Advisory Panel. I believe that is the name—have they been submitted to that panel for that panel's review of whether they in fact should be funded if we are going to fund SSC or not?

Dr. LEDERMAN. Well, this has been very actively discussed. It is a continuing process, and at the moment the panel, which had a recent review of the situation, is punting, in the sense that they are still watching to see what Congress does with the SSC in the fiscal '90 budget, but certainly all of the gleams in the eye all the way down to specific proposals have been put forward to the HEPAP. So they are very aware of this, and they go around and continuously review these programs.

Mr. SCHIFF. I just want to observe, Madam Chair, that I, for one, would certainly need the advice of such a panel in terms of knowing what we should proceed with and what would be cost effective and beneficial to the high energy physics community, even assuming we do authorize the SSC, just so there is a continuum that makes sense both in terms of the physics community and in terms of funding.

Thank you, Madam Chair.

Mrs. LLOYD. Your point is certainly well-taken.

The Chair at this time would like to recognize the highest ranking Republican on the full committee, Bob Walker. We are happy you are with us again, Bob.

Mr. WALKER. Thank you. Thank you, Madam Chairman.

I think my colleagues have asked a number of the important questions here. Let me try to fill in a couple of details, though, for my own thinking.

We spend about $10 billion a year right now on basic research, isn't that right, and of that high energy physics gets about a billion of that, about 10 percent?

Dr. LEDERMAN. $.6 billion. $600 million.

Mr. WALKER. $600 million. Well, if you add in—I think the figure overall comes to about $900 million, doesn't it?

Dr. LEDERMAN. With the SSC, that is right.

Mr. WALKER. With the SSC we are at about 900 million, and we will have a ramp-up of money for SSC over the next several years, so that at that rate—I mean at the rate we are at right now—we are at about—well, .9 of—9 percent of the overall basic research money is in high energy physics at the present time.

Does anyone believe that we are likely to move much beyond that figure and that the scientific community would accept moving beyond the 9- to 10-percent range for high energy physics as a component of basic research?

Dr. RICHTER. I think most of the high energy physicists would hope that the percent of high energy physics goes down while the money stays the same. I think that Leon expressed it very well earlier. It is very important for the United States to invest in basic science. It is the engine that keeps technology running. I think there has even been a Nobel Prize in economics recently showing that all economic growth comes from the development of new technology and that in turn comes from basic research.

Mr. WALKER. You won't find any argument on that issue in this committee on both sides of the aisle. The bottom line is, though, that—I think—that at the rates we are now expanding the science budget we can't find—we are not going to get much more out of the budgeting. We are doubling the NSF budgets over the next 5 years. The space budget is going up about 50 percent over the next 3 years. I mean, we are talking about fairly substantial levels of growth in scientific budgets coming in the authorization, the budget process, and the appropriations process, and so, you know, as we see these figures going out over the next few years, it is in fact a situation where we are going to have to struggle to hold on to those increases, let alone expect to go from $10 to $20 billion in basic research I mean, which is what I understood Dr. Lederman's testimony was.

We would love to do it, but I am not certain that that is the case, and I want to get to this percentage question because what I hear is not only competition within the high energy physics realm of things, but you are also beginning to get some people in the scientific community who are saying, hey, all of this work in high energy physics could impact on our ability to get the research dollars we need in basic research or in applied research or elsewhere.

And my question is largely along those lines. Do you think that we can anticipate the science community as a whole accepting a level of high energy physics activity which expands beyond the present 9- to 10-percent base?

Dr. LEDERMAN. I would like to try. I might just remind you about some numbers. In the 1960's, middle 1960's, high energy physics was 12 percent of basic research and slowly dropped, and that is a good sign because it didn't suffer. It dropped because there were other sciences competing for money and they were vigorous and they got their support, and it drifted down from 12 percent to a low of some 7 percent and now has come up to the number you just mentioned. Largely, the big increment is the SSC.

Mr. WALKER. Right.

Dr. LEDERMAN. Remember, that increment is a pulse. It will last a large number of years, but by five or six years into the project it will start declining. We don't expect that high energy physics will stay, and this happened at Fermilab. There was a big peak of funding for Fermilab for two or three years, and then the budget went back to something which was roughly the fixed percentage that you mentioned before, something like 7, 8, or 9 percent, probably less than 9 percent.

Mr. WALKER. But in the mid-1960s I would also remind you that we were spending 3.6 percent of the Federal budget on space activities, on civilian space activities, on NASA alone, so that, you know, again it would be wonderful to use those as examples, but we have to look at the realities of the 1990's.

I am also concerned about a statement, Dr. Schwitters, that you made, and that is that when we get to the point that SSC comes online, I think I understood you to say that at that point we are going to have scientists moving over to the SSC facility.

Dr. SCHWITTERS. That is correct. They will take their research. That will be the center for a lot of the research.

Mr. WALKER. Understand you are not dealing with scientists here. You are dealing with politicians.

Dr. SCHWITTERS. Yes.

Mr. WALKER. And politicians are going to be very, very suspicious of putting a lot of money into Fermi or into SLAC or into a lot of these other places if what you are saying to us is that when we get out to the end of the 1990's all of that investment is gone because the top people are all going to move out of those facilities over to the SSC, and you know, it is going to be awfully difficult to sustain a level of activity that gives us a high energy physics community if that is going to be the end result of the investment.

Dr. SCHWITTERS. Let me just comment a little bit.

Mr. WALKER. Okay.

Dr. SCHWITTERS. I said that at that time, 10 years from now, that is when the transition begins. There will be still—with the current plans that we know about from the laboratories, there is still an exciting and important research program that will be tailing off there. Again, that is how we have done it in the past. It is not an abrupt change, but it is a program that will take us and our students and young people through this decade of construction and then gradually a migration will take place. It is traditional in our field.

Could I make a comment on your first point?

Mr. WALKER. Okay, I will be glad to come back to you in just a minute, but I was in CERN within the last month and talked to Carlos Rubbia there, and he is concerned about exactly the same kinds of things that this panel has discussed and that I think some of you are sensitive to as well, and that is that we end up losing a great deal if in fact politicians look at all this evidence and decide, okay, we are committed to SSC but we are not committed to much else beyond that.

And I got to tell you, that is a very real possibility.

Yes, go ahead.

Dr. SCHWITTERS. Well, I was just going to say the other measure by which—you are trying to judge a percentage or somehow get a feeling for the support here—I think the other yardstick you can use to study this is the foreign competition, frankly. I mean, usually you go in the competition and measure how you match up with the others, and as we look around Europe now and Japan, we are seeing much higher funding in this area of basic research as a fraction of GNP than we are seeing in this country now. It didn't use to be that way. We have gone down; they have gone up.

So by that yardstick as well, you know, we are not going to have any argument that we need more support in this kind of basic science.

Mr. **Walker**. Well, again you don't have any kind of argument with that here. The problem is, of course, that we are going to hear from a whole range of scientists, all of whom will tell us the same thing and all of whom want priorities put in their particular area.

My concern is how we end up allocating that which we are willing to expand, but do so in a responsible way to make certain that we get basic research in a number of different areas and also in some applied areas. I mean, this committee is concerned about high definition television and a number of things where we have got real concerns as well.

Thank you, Madam Chairman.

Mr. **Barton**. Will the Chairman offer me the courtesy of giving a political answer to Congressman Walker's question?

Mrs. **Lloyd**. OK, briefly.

Mr. **Barton**. Congressman, I would put it in political terms. Not many people run for the U.S. Senate or the U.S. House of Representatives right off the bat. Most of our colleagues start out in the state legislature or the county commissioner's court. When they are elected to come to Washington, they don't burn down the courthouse or the statehouse. Somebody stays and takes their place.

There are exciting areas of research to be done at all of these lower energy facilities. The fact that we are going to have an SSC out there at 40 trillion electron volts, that is going to be the leading edge, but there is still tremendous research opportunities at the lower energy fields, and there will be scientists conducting that research just like we have state representatives and county commissioners meeting today while we are here in Washington.

Mr. **Walker**. Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much.

Thank you, gentlemen, for being with us today, and we look forward to your written replies as well.

Our next panel includes Doctor—if any of you would like to stretch for a minute, feel free to do so. You have been in here almost two hours now. If you want to stand up, I think it is called for at this time.

Our next panel includes Dr. William Wiley, who is the Director of Battelle Pacific Northwest Laboratories; Dr. Alvin Trivelpiece, Director of the Oak Ridge National Laboratory; Dr. Alan Schriesheim, Director of the Argonne National Laboratory.

I might say at this time that all three of our panelists are represented by a member on this side of the table.

Mrs. **Lloyd**. The subcommittee will resume its hearings now.

Mr. Morrison? The Chair recognizes the gentleman from Washington, Mr. Morrison.

Mr. **Morrison**. Thank you, Madam Chairman.

I am pleased to be able to welcome Dr. Bill Wiley. Bill is not only a renowned scientist, biologist, but he is the glue that holds together the diverse interests of Pacific Northwest Laboratories and also is a key player in our community.

Bill, we congratulate you on your new appointment as a regent at Washington State University.

Besides, he is just a neat guy, Madam Chairman.

Bill?

PANEL 2

STATEMENT OF DR. WILLIAM R. WILEY, DIRECTOR, PACIFIC NORTHWEST LABORATORY

Dr. **WILEY**. Madam Chairman, Mr. Morrison, and members of the committee, I have a detailed statement which I would like to have included in the record.

However, for the sake of time, I would just like to make a few remarks.

Mrs. **LLOYD**. Without objection, all of your complete statements will be made a part of the record.

Dr. **WILEY**. The first thing I would like to talk about is a continuation of the role of basic research in solving global and national problems that the United States will face. Certainly you have heard a great deal about the role of high-energy physics in this arena. I will talk primarily about small science and the role of that basic fundamental small science in solving some of the major problems of the country.

It is the beginning and the basis for most of the technological and global economic leadership that will occur over the next century. If we fail to recognize the relationship of small science and basic science and its importance to the major problems that the Nation will face, we may be in the business of fumbling away the future and perhaps mismanaging that future.

What is required here is to keep in perspective the important elements of basic science, how it derives the basis for some of the actions that the Nation will face. It is only through the conduct of this basic science that we will make progress in some of the things which I know you are concerned about. And these are global issues that are very, very complex, such as global environmental change, hazardous waste remediation, international competitiveness, and, of course, the education and training of scientists and engineers. All of these things are extremely important.

The next point I would like to make, Madam Chairman, is that the environmental issues that this country is facing will not be solved by the basic fundamental knowledge that we have today, but breakthroughs in basic fundamental knowledge that will come from increased investments in basic science and technology.

These new problems that we will face in the environment are not bound by national boundaries; therefore, the solutions to these problems are not regional, not local, and not national—they are global in nature. Solutions to these problems will require knowledge that does not exist today and that the national laboratories have been involved in, these very complex and global problems of the past and should be used as assets to make progress in these areas.

In addition, the national laboratories have always been associated with health and environmental research which offers a great possibility for basic fundamental scientific progress in the environmental areas.

PNL and other national laboratories are continuing to conduct research in the global environmental processes. For example, Battelle has made investments in this partnership with the Government, which has contributed to a new marine research laboratory located on Puget Sound. We have purchased a new aircraft for atmospheric research into the chemical transformation of atmospheric pollutants. Other laboratories have invested similar resources to complement the capabilities of these national laboratories.

It seems clear, then, that if we are to make progress on these global issues, increased investments are necessary and it is necessary that you set the appropriate priorities for these investments.

Last year—and this is my last topic—last year. I talked to you about the Molecular Sciences Research Center. In fiscal year 1990 the DOE budget contains $33 million operating and $3 million capital for this essential research element, which will be a center for science and engineering that is unlike any such facility and operational activity in the country.

With the commitment and support of DOE and the Congress, we will be able to keep this funding in the budget for 1990. A user facility will result from this investment. There will be products from this facility which will result in scientific principles and understanding of how hazardous waste behaves in the environment. New models of global transformations from the basic research that will be conducted in this operation will be made. Opportunities for training and education of scientists and engineers will be a result of this facility and investment.

The focal point for the Pacific Northwest Center for Science and Engineering will occur. This will be a center for scientific collaboration without walls, a center which speeds up the utilization of basic science in support of the needs of the Nation.

Let me summarize then, Madam Chairman. We have some challenging and difficult problems facing the Nation. Basic research is a fundamental requirement if we are to make some progress on these very significant issues. The time for that, the time for this decision process and making these priorities, is now. The need is for a sustained investment in the basic energy sciences program, in the general sciences budgets of DOE, to assure that the progress we have made thus far continues.

Thank you, Madam Chairman.

[The prepared statement of Dr. Wiley follows:]

Statement of

Dr. William R. Wiley

Director

Pacific Northwest Laboratory

Before the

Committee on Science, Space and Technology

Energy Research and Development Subcommittee

United States House of Representatives

Washington, D.C.

February 23, 1989

Introduction

Madam Chairman and Members of the Subcommittee, it is a pleasure for me to be here today on behalf of the Pacific Northwest Laboratory (PNL) to discuss the Basic Energy Sciences and General Sciences programs in the Department of Energy's FY 1990 budget request. In my testimony before your subcommittee last year, I discussed the very important role that a strong basic research component represents for this country's continued technological leadership and economic strength. Several recent reports from prestigious organizations have similarly pointed out this relationship.

In his February 9 Message to Congress, entitled Building a Better America, President Bush laid out the new Administration's strategy for economic growth and competitiveness. Within this strategy were the following principles:

> "Science and technology are increasingly critical to the Nation's national security and economic health." (p.33)
>
> "Federal investments in research and development should be increased even beyond the current strong levels. Such investments should focus on basic research." (p. 36)

The subject of today's hearing is really one of the means by which the President is responding to several recommendations of the National Academy of Sciences, the Council on Competitiveness and other organizations, on this topic.

The Department of Energy's Role in Basic Research

The research programs within DOE's Basic Energy Sciences and General Science budgets are the fabric for much of the basic research capability in the national laboratories and many university research groups in this country. These resources, while only a small fraction of America's overall research and development community, are nevertheless extremely important. This capability has made significant contributions to our knowledge and understanding of many scientific problems. It also has resulted in a whole array of scientific accomplishments. The list of inventions, patents, IR-100 Awards, and spin-off companies resulting from the research supported by these programs is outstanding. Even Nobel Prizes have emanated from this research. These programs, including the large user facilities supported by DOE's General Sciences and Basic Energy Science budgets, are truly national assets and deserve continuing strong support from Congress.

Madam Chairman, I suggest that we not rest on our laurels; we must build upon the Department's accomplishments to address the problems that confront us today and in the future. I need not recount the issues relating to international competitiveness and scientific leadership that can be realized from DOE-sponsored research; these are well known to all of us. I will, however, list just a few issues facing this country that also will require the commitment of the talent supported by the Department of Energy: hazardous waste remediation, global climate change, and acid rain.

The progress that has been made in attaining the current standard of living in the industrialized world is in a large part attributable to the role of science and technology. Science has also helped us recognize that, in our progress, we have created problems relating to protecting human health and the environment that need to be addressed. We must now use science and technology to solve some of these problems that not only threaten our future progress, but also represent barriers to progress for the people of the lesser developed countries of the world.

The Environmental Challenge

I suggest to the Committee that several issues relating to "the environment" are national -- even international -- in scope and impact and need to be addressed in a dedicated manner with the scientific talent and equipment available at the national laboratories. The environmental and health related problems resulting from national security missions and energy-related activities require our immediate attention. President Bush recognized this fact in his recent Message to Congress:

> "The protection of the environment and the conservation and wise management of our natural resources must have a high priority on our national agenda." (p. 92 Building a Better America)

Accordingly, the Administration has committed to address the issues of clean air and water, ocean pollution, global environmental change, waste minimization, and hazardous waste cleanup. This commitment will require new approaches and sophisticated equipment to solve these problems in a cost effective manner.

Along with several other national laboratories, PNL has always been recognized for its health and environmental research. Moreover, Battelle has supplemented these capabilities with a new marine research laboratory on the shores of Puget Sound and a new aircraft with state-of-the art atmospheric monitoring equipment. We also manage at the Hanford site an Arid Lands Ecology preserve which provides a pristine "laboratory" for research on desert ecosystems. Other laboratories have other resources that can be applied to the environmental challenges facing us. The question for the scientific community is not can we solve these problems, but rather, the real question is how can we marshal our resources to solve them in the most cost-efficient yet effective manner.

The Molecular Sciences Research Center

In my testimony last year to this Subcommittee, I pointed out that PNL was in the early stages of developing a basic research initiative centered around the molecular sciences that would, among other features, provide a new capability for PNL and DOE for dealing with problems affecting our environment. This initiative also envisions a unique "user" facility ultimately being constructed to support research programs at PNL that would also be available to the national research community. Over the past four years, we have invested nearly $10 million in Phase I of our plans: i.e., developing the MSRC concept and submitting a formal proposal to the Department.

Since my appearance before the Subcommittee a year ago, much has been accomplished on the Molecular Sciences Research Center:

- Research themes have been developed which will form the basis of four Research Groups. Research programs have been developed around the theme of "Chemistry at Interfaces."
- Peer reviews have been conducted on the overall research themes and equipment configuration plans for the laboratory.
- Several new scientists have been recruited to participate in the laboratory's existing research programs which underlie the MSRC.
- Search committees have been formed to recruit a Director and Research Group Leaders.
- Approximately 30 visiting scientists from other laboratories, industry and universities have conducted seminars at PNL on various topics relating to molecular sciences.
- Equipment has been purchased and existing laboratory space has been converted to establish an interim molecular modeling laboratory.

The FY 1990 budget for Basic Energy Science contains the initial funding ($3.0 million in Operating and $3.0 million in Capital

Equipment) to move us into Phase II of our plans. I should also note that conceptual design has been completed for the permanent laboratory and we are prepared to begin the advanced design when funding is available. Your support is absolutely critical to continued progress. Your support is also very important to the Department of Energy's ability to solve some of the environmental issues described earlier.

The "Pipeline" for American Scientific Leadership

> "The national interest requires a greater commitment to science and mathematics." (p. 56, Building a Better America).

In this age of big science and "super" projects such as superconducting supercollider, superconductivity, supercomputers, supersonic aircraft, superkids, etc., we tend to forget the fact that we need a large number of individual talents to accomplish the "super" projects. The number of children who are pursuing mathematics and science curricula in our schools is alarming. As a country we must do something to motivate more of our children to pursue these curricula and become the scientists and the engineers of the next century. It is unacceptable for us to have less than 2% of a typical high school freshman class end up graduating from college with a Bachelor of Science degree in the natural sciences or engineering. Worse yet, the percentage decreases to approximately 0.25% for those who end up getting a Ph.D. The Department of Energy has supported a series of initiatives to try to "influence" children at an early age by means of honors institutes at the national laboratories, Saturday academies, teacher training programs, etc. I urge the Committee to provide strong support to the Department's science education programs aimed at the pre-college level. Everyone in this country has a stake in this issue and every public and private entity must do more than its fair share to create more interest in the sciences at an early age.

There is another dimension to the human resource issue that also deserves your support. There are a number of fellowships and other graduate student programs that are supported by DOE that are providing valuable experiences for the next generation of scientists and engineers. I urge the Committee to go beyond the current efforts of the laboratory/co-op and laboratory science education center programs to increase faculty and student training opportunities. The investment in these programs is an investment in the next generation of scientific leaders for the U.S.

The Pacific Northwest Center for Science and Engineering

> "Research partnerships between government laboratories, the private sector, and universities should be encouraged and facilitated to take better advantage of fundamental scientific advances." (p. 36, Building a Better America.)

The role of the national laboratories in assisting the universities with student and faculty research and training experiences has been longstanding with DOE. The university research community also represents a valuable asset for assisting DOE's laboratories in conducting their research programs. Over the past few years, I have been working with the major universities of the Pacific Northwest in an effort to combine the resources of PNL and the universities to create what might be called the Pacific Northwest Center for Science and Engineering. In this country today we are faced with unprecedented scientific challenges at a time when there are limited fiscal resources. The complexity of some of the problems in fact already exceeds the sophistication of the equipment available to solve them. Today's technology is often limited in meeting tomorrow's challenges. Thus, our approach at PNL is to develop a regional science and engineering "center" that can be shared by a larger community of researchers from other federal agencies, industry and academia in the Pacific Northwest. Bold new approaches involving interdisciplinary research teams with access to computers will be required to conduct research effectively. The Pacific Northwest has always been recognized for being in the forefront of many innovative technological and political solutions. We believe this "center" concept will be equally innovative and pave the way for scientific leadership in the 21st century.

SUMMARY

The programs supported by the Basic Energy Sciences and General Sciences budgets of the Department of Energy provide the basis by which America's technological leadership is preserved: A unique capability for solving significant environmental problems facing this country and, the resources for supporting the emergence of the next generation of our scientists and engineers. The President has recognized the importance of these programs. This Committee has always been a strong supporter of these programs. Now more than ever your leadership is required to preserve, indeed expand, the very programs that will have a significant impact on America's scientific leadership role in the 21st century.

Mrs. Lloyd. Thank you, Dr. Wiley.

It is now my pleasure to introduce Dr. Trivelpiece, who as I stated earlier is the Director of the Oak Ridge National Laboratory. And certainly Dr. Trivelpiece is no stranger to this committee, as the former Director for Energy Research for the Department of Energy.

Please proceed, Dr. Trivelpiece.

STATEMENT OF DR. ALVIN W. TRIVELPIECE, DIRECTOR, OAK RIDGE NATIONAL LABORATORY

Dr. Trivelpiece. Thank you, Madam Chairman, members of the subcommittee. It really is a pleasure to be back here again, although I must say I am somewhat shocked when I get up here to testify and half the audience is left. That never used to happen when I testified when I was the director of ER. I can't quite understand what has happened.

Mr. Morrison. You were doling out then, not spending. [Laughter.]

Dr. Trivelpiece. I see. Well, obviously, I used to defend these programs for the Department of Energy, was pleased to do so. I trust the committee won't be astonished if I give slightly higher emphasis to those activities that are associated with Oak Ridge now than I perhaps used to. I have only been there a short time and it has taken me some time to learn a little bit about the activities of Oak Ridge.

And obviously, one of the high priorities is the High-Flux Isotope Reactor. It was shut down for cause. We hope it will be restarted soon, and work is going on in that.

In that regard, Oak Ridge is certainly a center of nuclear research, and part of its future is tied up with the Advanced Neutron Source, which the department made some commitment to proceed with along with several other facilities at their national laboratories a few years ago.

There is a slight difference in the amount which the department seems to have requested for this activity in the amount which Oak Ridge believes would be appropriate for continuing it. Although the amount is small, I believe that it's a critical amount in that in order to properly request for a facility this size, it's necessary to know how much it costs, how long it takes, what the technical aspects of doing it are, are there any technical show-stoppers associated with it.

This process is usually referred to as the conceptual design report, and we need to get on with that particular activity right now, and the funds requested are for those to see to it that an adequate job can be done of preparing the proper conceptual design report.

Madam Chairman, I know that you have been concerned, as other members of the committee have, with the tech transfer aspects of the national laboratories. I think to some extent they do a better job than they are in fact given credit for. I used to talk about this from a DOE perspective, and now from an Oak Ridge perspective, I think as I have looked at Oak Ridge, I find it is doing extremely well.

In fact, some 28 licenses have been granted in the past few years as a result of inventions that have come directly out of the laboratories. One of them on making ceramic tools for lathes and so on has led to a company now locating in Oak Ridge to take advantage of the proximity to the laboratory.

But these things are kind of indexes of how well you're doing that are easy to document. I think that tech transfer also involves people as much as it does patents and licenses. And to that extent, the laboratory has some 2,300 guests each year now. Approximately a third of those are from industry. They work with laboratory scientists and on the various user facilities. They play a very important role in tech transfer, and it's hard to document that. But I believe that it is one of the areas where it's essential to keep that going.

In that sense, education is then a part of the laboratory; in other words, these other two-thirds of these 2300 guests are guest scientists and students who spend time at the laboratory working on and taking advantage of using the facilities.

To that extent, the Oak Ridge area benefits from a second GOCO facility, which is the Oak Ridge Associated Universities, and I understand Dr. Veigel will be talking about that later here. But we simultaneously benefit from the ability to utilize them and the laboratory for the benefit of educating students.

I know you are busy this morning, so I will terminate my remarks there, Madam Chairman. Thank you.

[The prepared statement of Dr. Trivelpiece follows:]

DEPARTMENT OF ENERGY'S FISCAL YEAR 1990 BUDGET

Alvin W. Trivelpiece
Director
Oak Ridge National Laboratory

Testimony Before the
Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
February 23, 1989

TESTIMONY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE SPACE AND TECHNOLOGY
FEBRUARY 23, 1989

Alvin W. Trivelpiece
Oak Ridge National Laboratory

Madam Chairman and Members of the Subcommittee, I am pleased to have this opportunity to testify before this Subcommittee in my new role as Director of Oak Ridge National Laboratory (ORNL). I have enjoyed testifying before this committee many times in the past, and I look forward to being able to tell you about the excellent programs of basic and applied research at ORNL. This Subcommittee is to be commended for its strong support of research and technology that has benefited our nation. While I was at the Department of Energy, I appreciated your interest in all of its research and technology programs. I still do, but I now particularly appreciate your interest and concern for those activities at ORNL.

FY 1990 BUDGET

The FY 1990 budget for the Basic Energy Sciences (BES) and General Science programs proposed by the Administration reflects the effort to maintain a balanced program and control spending. The funding issues surrounding the High Flux Isotope Reactor (HFIR) and the Transuranium Processing Facilities at ORNL have been adequately resolved by the Department of Energy. The Subcommittee's support of the HFIR and its nationally important isotope production and research activities is greatly appreciated.

The Advanced Neutron Source (ANS): The proposed ANS would be a world class facility for basic research using a reactor as a neutron source. It and its associated experimental facilities would replace the HFIR. We cannot maintain the planned construction schedule with the funding level proposed by DOE for 1990. The present schedule anticipates completion of construction and beginning of operation by about 1999. To meet this schedule, it is necessary to prepare for an FY 1991 design only line item request. To accomplish the required FY 1990 ANS activities, a budget of $9.7M is needed. This would require the addition of $5.2M to the proposed budget.

The ANS is one of the facilities needed for research conducted under the sponsorship of the BES program. With the support of DOE and this Subcommittee, our FY 1988 and 1989 budgets have allowed us to make good progress in the needed R&D. Work on a conceptual design has begun. Concurrent safety analyses are providing valuable input for the design of the reactor. A corrosion test loop has been constructed to test potential fuel cladding materials in water with the chemistry, velocities, temperatures, and pressures anticipated for the ANS. Workshops have been held to discuss safety aspects and materials considerations. The ANS National Steering Committee has provided guidance on the instrumentation requirements for neutron scattering, the needs of the isotopes community, and the provisions necessary for materials irradiation experiments.

The ANS has benefited greatly from the combined efforts of personnel at ORNL, Idaho National Engineering Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Babcock and Wilcox, the University of California-Santa Barbara, the University of Tennessee, Georgia Technical Institute, and the University of Virginia. Reduction of our proposed FY 1990 budget would result in the loss of trained staff and would delay the start of construction of the reactor by at least one year.

High Flux Isotope Reactor: The HFIR has been shut down since November 1986. To the best of my knowledge, the remedial activities required for restart have been completed. We are now awaiting final approvals by DOE. When approval is received, a controlled, disciplined, three-phase restart procedure will begin. A deliberate and conservative approach will be followed. Low power operation will be attained two weeks after the approval to restart. Final 85KW operation will be approached in a stepwise fashion.

Since the problem with the HFIR pressure vessel was discovered, the technical aspects and the management of the reactor have been assessed by 18 committees, including the National Academy of Sciences Committee and 12 committees appointed by DOE. Our restart activities have addressed the recommendations of each of these Committees. The continued use of the HFIR pressure vessel has received complete endorsement by the HFIR subcommittee of the DOE Advisory Committee for Nuclear Facility Safety (the Ahearne Committee).

As part of the progress over the past year, the Level I Probabilistic Risk Analysis and Seismic analysis have been finished. Also completed are the initial Comprehensive Safety Appraisal and upgrade programs. Our reactor staff has more than doubled to accomplish the activities important to safety. We have added additional reactor operators, more oversight and quality assurance personnel, and supplemental engineering and training staff. Safety is a top priority.

To ensure continued safe operation of HFIR, we have established an external independent review committee in addition to a strong commitment to periodic internal self-appraisal. An FY 1990 line item construction project has been approved by DOE for safety improvements to the reactor building and support facilities. The pressure vessel will be retested after every year of operation. Safety analyses and related analytic activities will also be an important part of our operations.

Holifield Heavy Ion Research Facility (HHIRF): The HHIRF is the center piece of nuclear physics research at ORNL. It is also a major focus of physics research and physics graduate student training in the southeastern United States. Each year over 200 university personnel visit the HHIRF to interact and collaborate with the staff; over half of these are actively performing experiments at the accelerator. During the past year, the participants in the experimental program at the Holifield included 44 graduate students.

Ongoing operation of the Holifield is a top priority in our Nuclear Physics program. The proposed budget for operations for FY 1990 has been reduced. We are working with DOE to minimize the impact of the decrease on our user operations.

The Recoil Mass Separator was recently funded for design and construction at the HHIRF. This device will allow advanced studies of short-lived exotic nuclei far from stability, a regime of interest for fundamental nuclear physics experiments. This $2.2M facility is jointly sponsored by ORNL, Idaho National Engineering Laboratory, the State of Tennessee, the University of Tennessee, Vanderbilt University, and other southeastern universities. The DOE-supported fraction of the funding is only 20 percent. The additional capability provided by the Recoil Mass

Separator would be further enhanced if coupled with the Gammasphere, a proposed national 4π gamma-ray detection facility.

The capabilities and experimental equipment available at the HHIRF continue to improve and expand. In the past year, an upgrade was completed that allows operation at 25.5 million volts - a new world record for tandem accelerators. This improvement was made possible by a new acceleration tube developed jointly by scientists and engineers from ORNL and the National Electrostatics Corporation. The HHIRF also includes the University Isotope Separator at Oak Ridge (UNISOR), an instrument funded by Oak Ridge Associated Universities (ORAU), a private, not-for-profit consortium of more than 50 colleges and universities. Recently, ORAU added a Nuclear Orientation Facility to UNISOR. This is a unique device for the study of nuclear structure. The first experiment with this new equipment involved 20 researchers, including 14 faculty members and students from 8 different universities.

The HHIRF is also an important part of our BES Atomic Physics program. To enhance our atomic physics capabilities, a Heavy Ion Storage Ring for Atomic Physics (HISTRAP) has been proposed to BES for construction beginning in FY 1990. The estimated construction cost for HISTRAP is ~$17M. HISTRAP would be an addition to the HHIRF and would expand our capabilities to allow experiments that require a large current of highly coherent ions. The HISTRAP has been strongly endorsed by a committee appointed by the National Research Council of the National Academy of Sciences to study the need for such a facility.

ORNL has been developing prototypes of major components of the HISTRAP. For example, to operate this device an unusually high vacuum is required (~10^{-12} torr). This has been achieved at ORNL with a vacuum test modeling 1/16 of the HISTRAP storage ring.

University Support: Universities play a vital role in ORNL's programs. Our relationship is mutually beneficial. Jointly sponsored research and other interactions provide access to unique facilities and invigorating discussions. The HHIRF discussed above is an outstanding example. In 1988 ORNL had over 1400 guests from universities collaborating with our staff and working with our user facilities. In addition, universities do R&D for ORNL. In FY 1988, nearly $20M, or 4.8 percent, of ORNL's budget supported R&D subcontracts at universities.

Scientific and technical training of students is important to the nation's future. To be competitive in the future, the nation needs sufficient technical staff. Closer ties with schools and universities can help this situation by inspiring our youth, including minorities and women, to consider careers in science and engineering. Beyond our user facilities, ORNL participates in numerous programs designed to provide research experience for students. Faculty involvement is also an important part of our programs. Support for these programs is through the DOE University Laboratory Cooperative Program, as well as through other ORNL R&D programs. Special funding is used for participants from historically black colleges and universities. Laboratory staff also travel to universities to present lectures and participate in university-sited research collaborations.

ORNL has close ties with several university consortia, including the Southeastern Universities Research Association, the Great Lakes Colleges Association/Associated Colleges of the Midwest, and the Southern College University Union. About 105 co-op students were employed by ORNL last year. In addition, there were about 200 students with formal research-participation appointments.

A unique pioneering science and technology alliance involving three national laboratories (Oak Ridge National Laboratory, Sandia National Laboratory, and Los Alamos National Laboratory) and three minority educational institutions (North Carolina Agricultural and Technical State University, New Mexico Highlands University, and the Ana G. Mendez Educational Foundation in Puerto Rico) was forged by the Department of Energy in 1987. This historical alliance is developing rapidly and successfully. All members of the alliance are working together to share resources in science and technology in a synergistic way.

ORNL's precollege activities have greatly expanded. In 1988, we hosted one of the DOE National High School Honors Workshops. The focus was environmental sciences. Another Special Honors Study program implemented at ORNL in 1986 allows exceptional high school students to conduct a study project under the supervision of a staff member. Seven students participated in 1988, bringing the total since 1986 to 12. A new program, the Summer Educational Experience for the Disadvantaged (SEED), has been instituted to encourage economically disadvantaged high school students to consider careers in science and mathematics.

The Ecological and Physical Sciences Study Center is one of the most visible and successful of ORNL's precollege programs. Since its inception in 1983, the Study Center has hosted over 8000 participants. The Center provides hands-on learning in both the physical and life sciences. The programs can be tailored for individual groups at any academic level - elementary through senior high school.

RESEARCH HIGHLIGHTS

I would now like to tell you about some research highlights from our basic science programs. Two years ago, this Subcommittee heard about an explosives detector developed by our analytical chemists. This device can detect conventional and plastic explosives through the minute quantities of vapor emitted by the explosive to the surrounding environment. Since the initial development, the detector has been patented and is now licensed to Finnigan Corporation for commercial production. There have also been improvements in the resolution and sensitivity. The system is very fast; it can detect TNT at levels below 150 parts per billion with sampling times of a hundredth of a second. The device has numerous commercial applications. For example, it might have been capable of detecting the type of explosives involved in the crash of Pan Am Flight 103. Other potential applications include detection of drugs, a much more complex problem than the detection of explosives.

ORNL has an active program in superconductor research. Since being named one of DOE's Superconductivity Pilot Centers, we have signed cooperative agreements with two industrial participants, General Electric and American Superconductor Corporation. Negotiations are in the final stages with six additional companies. To date, seven more companies have entered preliminary negotiations.

Our basic superconductor research program has also been quite successful. The current carrying capacity of thin films produced at ORNL by evaporation techniques has reached about four million amperes per square centimeter at liquid nitrogen temperatures, a factor of eighty increase since last June. In order to use these thin films in many electronic devices, it is necessary to deposit the superconductor on appropriate substrate materials. The interactions of the substrate with the superconductor can destroy the superconducting properties. ORNL staff have found that a new substrate material, potassium tantalate ($KTaO_3$), is much better than previously used materials. In addition, it can be produced at a lower cost and with larger areas than previously used substrate materials, making it a practical material for large scale electronic devices.

Characterization of the structure of the high temperature superconductors on an atomic scale is important to gain a fundamental understanding of the materials and the factors that impact their properties. A new technique that takes advantage of the different charges on the nuclei of different atoms has been developed for high resolution scanning transmission electron microscopy. This technique allows study of interfaces and defects in the superconductors with atomic resolution. A better understanding of how the superconducting pathways are broken by internal structural features, such as grain boundaries, defects and impurities, has been obtained.

In our autonomous robot research program, the next generation of the HERMIES (Hostile Environment Robotic Machine Intelligence Experiment Series) robot is nearing completion. HERMIES III has a manipulator arm with human-like manipulative capabilities with a 56 inch reach and the ability to lift 30 pounds. To allow this enhancement, the robot has grown - HERMIES III is about the height of a person (twice the height of its predecessor) and weighs 3000 pounds. It will also have enhanced vision abilities; a high-resolution laser rangefinder has been incorporated that will permit modeling of its surroundings in three dimensions. The latest models of the HERMIES robots are controlled autonomously by advanced on-board computers. These robots provide a unique facility for research in intelligent machines.

ORNL was one of the first DOE laboratories to move into the development of algorithms for parallel computers and to consider application of parallel computing to research problems. We have now expanded our efforts to include Grand Challenge Problems. Through the combined efforts of our physicists and mathematicians, preliminary codes for parallel computing have been generated for two calculations, electron correlation in high temperature superconductors and lepton pair production in relativistic heavy ion collisions. Both codes are being fine tuned and have high projected efficiencies. It is clear that large machines will be essential for these types of calculations. With the current ORNL hypercube, the time required for a single computational experiment is estimated at 300 hours for the superconductor calculation and about a month for the lepton production problem. Multi-gigaflop machines will be required to make these calculations feasible. In the future, ORNL hopes to be the site of such a machine to serve as part of an advanced computing laboratory with communications networks to the southeastern universities as well as the rest of the nation.

Mrs. **Lloyd**. Thank you, Dr. Trivelpiece.

Mr. Fawell?

Mr. **Fawell**. Thank you, Madam Chairman.

I am not sure what that buzzing sound is all about.

Thank you. I just want to take this opportunity. It is always delightful to see Alan Schriesheim before this Committee, and I know we all are grateful for your opening Argonne Lab to the hearings which we held on February 10 back in the 13th Congressional District.

But Dr. Schriesheim is very well respected in our district. He has a background in basic research and industry as well as at the National Lab category, and at Argonne, under his leadership, Argonne has become well known for its technology transfer programs and superconductivity and the advanced-reactor research at the lab and a number of important areas.

So, Alan, it's good to have you here and to introduce you into the subcommittee. Unlike Dr. Letterman, you shall be coming back again, for which I am thankful.

Mrs. **Lloyd**. Dr. Schriesheim, I would also like to thank you for your hospitality when we visited your laboratory. We were very impressed.

Please proceed.

STATEMENT OF DR. ALAN SCHRIESHEIM, DIRECTOR, ARGONNE NATIONAL LABORATORY

Dr. **Schriesheim**. Let's see, is this microphone on? Yes.

Well, Madam Chairman, members of the subcommittee, I am pleased to be here. I might take just a half a second and say I am doubly pleased to be sitting on the same side of the table with Dr. Trivelpiece. [Laughter.]

For a personal reason. That is that Al was key in my accepting the job at Argonne National Laboratory. He really convinced me that that would be an interesting thing to do, and it has turned out to be that way.

Because of the time limitation, I have a more detailed statement which I will put in the record. I have selected issues to discuss that are important not only to the laboratory but to the national enterprise generally.

I start with the 7-GeV synchrotron, the advanced photon source. From our perspective, this is the most important budget item. It is $40 million construction funding start for the advanced photon source for Argonne. The many prospective users of the photon source are really pleased that we will be able to get on with the construction of this vitally important research facility.

The advanced photon source will have as many as 70 laser-like X-ray beams for use by all segments of U.S. science and technology. The beams will be used to determine the atomic structure of materials that underlie all modern technologies: catalysts, pharmaceuticals, semiconductors, structural alloys, supercomputers, to name just a few.

I would like just briefly to go through the chronology to show the steady progress that we have made in developing the advanced photon source, and also to point out that this has been peer-reviewed. It has been through a lot of peer reviews.

In 1983, planning began for a national facility to produce hard X-rays. In 1984, the Department of Energy and the National Academy of Sciences designated the facility, the photon source, as having the highest priority for materials research facility. In 1985, DOE selected Argonne as the site for the project. In 1986, DOE approved Argonne's conceptual design.

In 1987, Argonne refined and improved the design. In 1988, Argonne began to prototype and test the key machine components. And in 1989, the project received line-item funding although we were forbidden to actually construct. An architect-engineering firm was selected and detailed design work began.

Now, by the beginning of this year, we had assembled a project team of some 50 scientists and engineers. We are recruiting 30 more for the construction start in 1990. David Moncton, the winner of the 1987 Lawrence Award and a leader in the synchrotron radiation user community, has joined the laboratory as the associate laboratory director for the photon source project.

So, although progress has certainly been steady, each year the program has been obviously funding-limited. As a result, the Europeans are proceeding, have proceeded, they have raced forward with a similar facility to be constructed at Grenoble. I visited that just a few months ago.

The Japanese, who were further behind, have taken advantage of the early design work that we have done. And they have caught up. Their machine will have a major center actually associated around that machine. It will be a major facility in Japan.

So, it is hard to conceive of a research facility as important to U.S. competitiveness in so many different scientific and technological fields. We have broad support across all of those fields that I mentioned earlier.

I strongly urge Congress to adopt the administration's budget request for the advanced photon source.

Also, of course, I would point out that I support the administration's request for these other facilities—the neutron source, the heavy ion collider, and the 1-to-2-Gev synchrotron—that all have major implications across a broad spectrum of user communities.

That brings me to this point of funding of the BES user facilities, because another bright spot certainly in the basic energy sciences budget submission is the increased support for the operation of the existing user facilities. The university and industrial interest in these facilities has expanded greatly in recent years, while operating funds have remained limited. The administration's budget request for 1990 is a major step towards expanding these important national facilities.

Superconductivity, Argonne is in the forefront of the national effort to exploit the potential of the new superconducting materials. We, Oak Ridge, and Los Alamos are a pilot center for R&D on superconductivity. We were the first national lab to have one of its inventions on superconductivity licensed to the private sector. None of these initiatives would have been possible without DOE's strong support and encouragement, and we strongly support the additional $4 million to the BES superconductivity research budget in fiscal year 1990.

In applied mathematical sciences, there has only been a nominal increase in that. We would like to recommend that DOE consider the recommendations of the FCCSET committee, this Federal Coordinating Council for Science, Engineering, and Technology, and adopt a more aggressive posture in the nationally important computing research area.

In the area of general science, we certainly agree with the thrust of DOE's programs in high energy and nuclear physics. That includes the construction start for the superconducting supercollider. I agree, of course, with the earlier panel that this should be done in an incremental fashion, obviously in incremental fashion.

I would be remiss, although I know that the subcommittee will hold hearings on March 1 on fission energy, if I didn't point out that the Integral Fast-Reactor program at the laboratory has a budget request that is down $23 million from what it was: $6.1 million, down from $29.2 million in 1989. The Integral Fast Reactor is an important leaf in the Nation's energy portfolio. As I say, I know that this committee will have separate hearings on this next week, and I of course strongly support it. I hope the committee supports it.

In educational programs, we were somewhat disappointed by the budget submission for university research support, particularly for the request for the lab cooperative research centers. I believe that the labs are prepared to do their share in helping the Nation meet what people describe as a crisis in science and engineering education. And I would recommend that the committee consider increasing the budget for DOE's educational programs.

I will end with just a comment on technology transfer. Madam Chairman, the committee held an exceptional hearing, I believe, at Argonne National Laboratory to discuss specifically the issue of technology transfer. I am quite pleased that Argonne is certainly up front, you might say, in the arena of technology transfer. We have a lot of good specifics, but more importantly, the national laboratories themselves are important leaves in the Nation's competitiveness, national competitiveness issue. We expect to remain that way, and that is something that we should all keep in mind when we think about the support of these nationally important facilities.

It is an honor, Madam Chairman, for Argonne National Laboratory to host those hearings two weeks ago. It has been a privilege to appear before you today.

[The prepared statement of Dr. Schriesheim follows:]

Testimony Before the

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT OF THE HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

by

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Director of Argonne National Laboratory

February 23, 1989

Madam Chairman and Members of the Subcommittee, I am Alan Schriesheim, Director of Argonne National Laboratory. I am pleased to have this opportunity to comment on the budget submission for the Basic Energy Sciences and General Sciences programs of the Department of Energy.

Because of the time limitation, I shall be able to comment only on a few budget items. I have selected ones that are important not just to my laboratory, but to the national R&D enterprise generally.

7-GeV Advanced Photon Source

From our perspective, the most important budget item is the $40 million in construction funding for the Advanced Photon Source. Argonne and the many prospective users of the APS are pleased that we shall be able to get on with the construction of this vitally important research facility.

The APS will produce as many as 70 laser-like x-ray beams for use by all segments of U.S. science and technology. These beams will be used to determine the atomic structures of materials that underlie all modern technologies -- catalysts, pharmaceuticals, semiconductors, structural alloys, and superconductors, to name a few.

A brief chronology will show the steady progress we have made in developing the APS.

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Although progress has been steady, each year the development program has been funding-limited. As a result, the Europeans have raced forward with a similar facility. They are now two years ahead. The Japanese, who were further behind, have caught up. Moreover, the Japanese machine will have 50-percent greater capacity than the APS.

It is hard to conceive of a research facility as important to U.S. competitiveness in so many scientific and technological fields. I strongly urge that Congress adopt the Administration's budget request for the Advanced Photon Source.

Funding for BES User Facilities

Another bright spot in the BES budget submission is the increased support for the operation of existing user facilities. University and industrial interest in BES facilities has expanded greatly in recent years, while operating funds have remained limited.

A good example of the situation is Argonne's Intense Pulsed Neutron Source, which is oversubscribed by a factor between two and three, despite our having doubled the neutron flux by installation of the new uranium target. Research by scientists from industry, universities, and government laboratories is being rejected because we do not have funds for the staff needed to assist the large user community. Other DOE neutron and synchrotron-light sources are similarly constrained.

The Administration's budget for FY 1990 is a major step toward expanding access to these important national facilities.

High-Temperature Superconductivity

Argonne is in the forefront of the national effort to exploit the potential of the new superconducting materials. We have the largest publicly funded program in the nation. Our work ranges from research on the fundamental properties of the new materials to ways to fabricate them into practical conductors.

DOE recently designated Argonne a Pilot Center for R&D on superconductivity. We are currently negotiating cooperative research arrangements with over ten industrial firms. We are a participant, with three Illinois universities, in the first NSF-funded Science and Technology Center on High Temperature Superconductivity. We were the first national laboratory to have one of its inventions on superconductivity licensed to the private sector.

None of these initiatives would have been possible without DOE's strong support and encouragement. The Department's leadership in redirecting work into high-temperature superconductivity was critically important. We strongly support the addition of $4.0 million to the BES superconductivity research budget in FY 1990.

Applied Mathematical Sciences

The budget submission for BES programs in applied mathematical sciences provides a 5-percent increase in operating funds. This nominal increase, about equal to the rate of cost escalation, means essentially no increase in the level of research effort in FY90.

I would recommend that DOE consider the recommendations of the FCCSET Committee*, and adopt a more aggressive posture in this nationally important research area. Experience with our Advanced Computing Research Facility indicates that there is a vast demand for access to advanced-architecture machines. Using telecommunications links, hundreds of off-site users are developing and testing software on ACRF's parallel-processing and advanced-architecture machines.

There is now a need for a DOE-sponsored "production facility" for parallel processing. As part of our initiative to establish a Center for Energy Research Computation, we are exploring the application of parallel processing techniques in a number of research areas: molecular dynamics of protein crystals, thermal hydraulics of fission-reactor systems, theoretical chemistry and high energy physics, and performance simulations of detector systems for the SSC. Progress on these and other computational problems is critically important to DOE missions and programs.

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We generally agree with the thrust of DOE's programs in high energy and nuclear physics.

The budget submission for Nuclear Physics will enable us to continue the upgrade of the Argonne Tandem Linear Accelerator System, to bring the Fragment Mass Analyzer into operation in FY90, and to proceed, with our four university partners, to develop the Positron Detector.

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The overall strategy for DOE High Energy Physics program appears to be balanced. We certainly endorse the increase in funding for development of advanced technology for future accelerators, colliders, and detectors.

In recent experiments at Argonne's Advanced Accelerator Test Facility, we demonstrated an acceleration technique -- "wake field acceleration" -- that could reduce the length of linear accelerators by as much as a factor of ten. We are now designing a 1.0 GeV prototype. This device will provide valuable information about the feasibility of this exciting type of accelerator.

Integral Fast Reactor

Having commented on the budget submissions for the BES and General Sciences programs, I would be remiss not to comment on the requests for several energy technology programs that are important to my laboratory and to the nation's energy future.

The budget request for Argonne's Integral Fast Reactor program is $6.1 million, down from $29.2 million in FY 1989. This reduction of $23 million would bring a halt to all major IFR development tasks.

The IFR is an innovative reactor concept that we developed several years ago. It exploits three main design features -- pool configuration, metallic fuel, and integral fuel cycle -- to minimize plant cost while ensuring inherent safety. Through successful development of a ternary fuel and new electro-refining technologies, we have established the basic feasibility of the IFR fuel cycle. We are now preparing to demonstrate the entire system at an Idaho site.

The Subcommittee will hear more about the IFR program at its hearings on Fission Energy. I would only point out that the IFR is truly a unique energy system, the only one I know that promises inherent safety, reasonable cost, unlimited supply of energy, and a solution to the Greenhouse Problem. An incremental allocation of $20 million will be required to continue development of the technology.

Fossil Energy, Conservation and Renewable Technologies

I am also distressed about the implications of the budget request for other areas of energy technology. Substantial cuts in the budgets for fossil energy and for most of the conservation and renewable energy programs will cripple many promising R&D efforts.

At Argonne, proposed reductions in these R&D budgets would severely curtail laboratory work in such areas as: advanced fuel cell technology; electric batteries; nitrogen-oxide and sulfur-oxide emission control; new methods for disposing of hazardous wastes; and basic studies on heat transfer and multiphase flow. I would urge that the Committee restore funds for these programs.

Educational Programs

We are disappointed by the budget submission for University Research Support, and particularly by the request for the Laboratory Cooperative Science Centers. This program brings many faculty and students into valuable research and education activities at DOE's laboratories. The budget request would eliminate entirely the nuclear engineering component, while holding support for the rest of the program constant.

Argonne operates the largest educational program in the laboratory system. One of our activities, the Student Research Participation program, brings 300 undergraduate students annually to the laboratory. As documented by a recent survey of previous participants, the program has been very effective in encouraging students to pursue advanced degrees and careers in science and engineering.

Through DOE's support, we have put in place programs that address educational needs from the pre-college through the graduate and faculty levels. Pre-college activities include summer science courses and research projects for high school students and institutes for high school teachers. At the graduate level they support thesis research. Each year more than 2,000 students, teachers, and researchers from over 270 institutes participate in our educational programs.

The laboratories are prepared to do their share in helping the nation meet the crisis in science and engineering education. I would recommend that the Committee consider increasing the budget for DOE's educational programs.

Technology Transfer

Just two weeks ago, Argonne hosted a field hearing by this Subcommittee. The focus of that hearing was Midwest R&D priorities and the roles of the federal government, DOE, and the national laboratories in meeting those priorities.

In testifying before the Subcommittee, I described the many cooperative programs that Argonne has developed with regional, state, local-industry, and educational organizations. As I tried to recount, these new associations have borne fruit beyond our expectations.

We have also sped up the transfer of new inventions to the marketplace. The organization mainly responsible is the not-for-profit corporation called ARCH that Argonne and the University of Chicago founded several years ago. This past week ARCH announced the establishment of a privately financed venture fund that will provide seed capital for new firms that develop discoveries made at the Laboratory and the University. We expect the fund to become an important pathway for commercializing laboratory innovations.

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Thank you.

PANEL 2 DISCUSSION

Mrs. LLOYD. Thank you very much, Dr. Schriesheim.

All three of you presented excellent testimony.

Two major goals for the subcommittee during the 101st Congress will be to promote the university research programs. We are, like you, dismayed that we did not have proper funding in the DOE budget for our education programs. Also, we want to work with you to enhance the role of technology transfer to create more wealth and more opportunity and to help our country pay its bills as well.

I know you are concerned, as I am, about some of the potentials for negative budget impacts of the SSC on other programs in the basic energy science and general science programs.

What are your views, say, in the light of the present budget pressures?

Would you like to start, Dr. Trivelpiece, with your new hat on?

Dr. TRIVELPIECE. Madam Chairman, as you recall, I had the privilege for a period of several years of being involved with this in the department and the opportunity and the honor to present to the President the case for proceeding with the SSC.

And in so doing, this involved many discussions with Secretary Herrington at the time about this and the issue always was why is this good for the United States, why is it good for America? I don't think the science was ever in question. It was always believed that the science would be beneficial, the knowledge gained would be beneficial, the technology would be beneficial and so on.

As you know, at the end of the Cabinet meeting in which they made this presentation to the President, he read this Jack London's credo which begins, "I would rather be ashes than dust," and goes on in that vein. And then he pointed out that this had been read to Kenny Stapler, who was then quarterback of the Oakland Raiders, and Kenny had been asked what the statement meant, and Kenny said it meant throw deep. [Laughter.]

Of course, that's how the President ended that particular Cabinet meeting. I think that he did so with the belief and understanding and hope that this was something that did involve going at the margins of the budget but that it was something for which the United States should in a sense throw deep, take a chance on doing this.

The understanding at all times was that this should not come at the expense of basic research. Now, the President did not provide guidance as to where it should come from, and I think he left that dilemma to the Congress. But all the time that we went forward with this it was at least that the administration would start out with the hope that that would not occur.

So, I believe that is still the case, that it should not come at the expense of basic research, but why does it have to be done on this basis of comparison of two goods? It is like the State of Oregon decided to cut out liver transplants in favor of prenatal care for mothers. That is a wonderful thing to do. And it was maybe the right thing to do when viewed one way.

On the other hand, why not not build a few more miles of road in the State of Oregon and still have the liver transplants take place? Why is it that this question is always formulated in a way that comes down between a choice of two goods rather than a choice against some other priority that the Nation might be considering.

I know that the structure of the appropriations in the budget committee doesn't make that easy for you to do.

Mrs. **LLOYD**. Well, that is exactly so. It has to come out of that budget function.

Dr. **TRIVELPIECE**. I understand that. But I think the point was that in proceeding with this, at the administration level it was the President's understanding that that should not occur, but in going so the manner he did it, he did leave the Congress with the dilemma. And you are asking the question in the context of that dilemma. And I would hope that it would still be possible to not necessarily take this from other areas of basic research.

Mrs. **LLOYD**. And we agree with you.

Dr. Wiley?

Dr. **WILEY**. I am not agreeing with him, because he is ostensibly responsible for my sitting here as well. [Laughter.]

But the idea here is that we must go ahead with basic science as well as the SSC. One cannot be sacrificed at the expense of the other.

Now, I do not envy the Congress in having to make that decision. In my remarks, however, I did state that it would be foolhardy and perhaps fumbling away the future or mismanaging if we were to ignore the need for continued investment in small, basic fundamental science because this is going to be essential to help us to solve some of the major problems we face.

Mrs. **LLOYD**. Dr. Schriesheim?

Dr. **SCHRIESHEIM**. Madam Chairman, like most, I am sure, of the other lab directors in this position, have given this some considerable thought. My thinking on that goes something like this: that the Nation, since the Second World War certainly has made some considerable investment in high-energy physics. There is a lot of, if you will, taking an industrial term, sunk costs in this country in that arena.

The people who run that community, who are after all among the brightest that we have in this Nation, have come forth with their conclusion, which is that the next generation of high-energy physics should be focused around this machine, the superconducting supercollider.

We have paid a lot to get that judgment. And these are people who are the leaders in the community, and to do something other than what they suggest is, in a way, not exactly throwing 40 years of investment down the drain, but I would think a long time before I decided not to do that because of that issue.

Now, once I have said that, it is certainly then a matter of how to do it. As I said earlier, and as the high-energy physics panel itself said, to do that at the expense of the rest of American science, who would agree to that?

And I do support what I consider to be a major investment that this country has made. We did it for some reason. So, before we decided not to fund it, I would think hard on it. A tough problem.

Mrs. **LLOYD**. Thank you a lot.

Dr. **WILEY**. Yes.

Mrs. Lloyd. Mr. Morrison?

Mr. Morrison. Bill Wiley, let's shift our basic science in a slightly different direction. I guess if the funding of the supercollider is an hour out of the Federal Government's fiscal time, the Molecular Science Center is but a sigh.

Dr. Wiley. Right.

Mr. Morrison. But it is a direction that I am intrigued with and, I think, for the record would like to have a little more thorough description of the intent of PNL in dealing with this opportunity.

Dr. Wiley. Thank you, Congressman, for that opportunity, because the Molecular Sciences Center is essentially a new way of doing science. The Molecular Sciences Research Center is a program which proposes to look in very special ways at the interaction of molecules whether in the solid form or the gas form or in the liquid form. It is the interface of these molecular structures that will become the basis for the knowledge of how things behave in the stratosphere, how chemicals behave in the atmosphere. It is the basis for determining where the atoms are on superconductors. It is a fundamental scientific approach to the linking of what I would call theoretical science and experimental science.

It is also a center which will provide the needs for enhancing science and educational training. It will be comprised of computational and collaboration computer equipment which does not now exist. The most comparable activity, our user facility, that comes along these lines is a center in Japan. There is no other such center in the world. And we are just absolutely excited about the prospects of such a center.

Mr. Morrison. I presume this has implications for the environment?

Dr. Wiley. Yes, it does, directly.

Mr. Morrison. And it is also tied in with local universities?

Dr. Wiley. We are calling this opportunity, Congressman Morrison, the opportunity to have an institution for science and engineering without walls, because we think that the technological changes which have occurred in the computational sciences as well as in computers and communications will permit us scientists to communicate in a manner that does not exist today and that the universities in the northwest and throughout the United States will be able to come together in what we are calling a national and regional center for science and engineering.

Mr. Morrison [presiding]. Thank you very much.

Mr. Fawell?

Mr. Fawell. This question of how do you fund the SSC without affecting the basic sciences reminds me of the story where one asks a spiritual seer what is the secret of spiritual truth, and he answered, "I am, that I am." And he said, "Well, thanks for clearing that up for me." [Laughter.]

Sometimes I think we keep throwing that question at you folks, and I guess in the final analysis obviously we are the ones who have to make some of those decisions.

Speaking of some of these other basic sciences, Dr. Schriesheim, I know, of course, that the Japanese and Europeans are building a similar machine for the APS, but if funds were delayed for the

APS, would our industries get access to those overseas machines, do you think?

Dr. SCHRIESHEIM. All of these machines operate on the basis of peer proposal, basically are proposals. The existing machines are saturated. There are more proposals than there is beam time. I would expect that on a scale of zero to ten, we would be pretty close to a ten that the European Community would saturate its own machine. And the Japanese would clearly saturate their machine.

So, there would be some time available, but it would not anywhere near be what the industrial sector of our society would demand.

I would point out that just recently we had a group of eight pharmaceutical companies come to the laboratory. They are forming a consortium, and that consortium will occupy one beam line or two beam lines, depending upon what they finally decide. And I know they are serious because this group of eight companies brought 15 lawyers in order to negotiate this particular deal with the laboratory. [Laughter.]

In addition to the issue of saturation, of course, there is another issue, in that if we decide to go forward with this, then we should decide to go forward with it. Pushing back or lowering the cost and the schedule, of course, increases the cost of the facility ultimately and decreases the efficiency with which it will be built.

It is particularly painful, though, I must say, to see us slip from a leadership position, which is what we were in, to a position where we are barely even and clearly falling behind vis-a-vis these other two machines.

Mr. FAWELL. And the Japanese, as I understand it, are using our design.

Dr. SCHRIESHEIM. Essentially. Essentially. There is in this community a sharing of basic machine design information. And that certainly has put them in a position where they didn't have to do a lot of that early work, yes, that's true.

Mr. FAWELL. Just one other question. What other industries do you expect to make the most intensive use of the APS?

Dr. SCHRIESHEIM. It's a materials machine. That is, the machine is geared to give us an understanding of what goes on with materials. The application then is broad, ranging from:

The health industry, we have the ability to do noninvasive angiography; there will be three medical beam lines that will be constructed. The pharmaceutical industry will use it to design better drugs, give us a handle on the nature of viruses and proteins; synchrotrons have already been used for that.

Industry, the whole aircraft industry, the turbine, advanced turbines, for example, will benefit from an understanding of what goes on in alloy, alloy composition and structure.

The petrochemical industry is almost completely dependent upon catalysts which really form the basis of our whole gasoline, heating oil, diesel fuel, and so forth, production. This will enable companies such as Exxon and Schlumberge, which are already involved with those; Amoco, involved in a very detailed way in examining the surface of catalysts so that they can design better catalysts.

The electronics industry, with a more detailed understanding of what goes on on the surface of integrated circuit chips.

So, in the sense that you asked that question, it is almost impossible to finger an industry that will not benefit from this particular machine, as well as academia, of course, which will also be very much involved.

Mr. **Fawell**. All right. Thank you.

I have no further questions, Madam Chairman.

Mrs. **Lloyd** [presiding]. Thank you very much.

Mr. Schiff?

Mr. **Schiff**. Madam Chairman, I have no questions for the distinguished panel.

I would like one minute to make an observation, with your permission.

Mrs. **Lloyd**. Go right ahead.

Mr. **Schiff**. With respect to Dr. Trivelpiece, whom I have never met but whom I know by reputation and think very highly of there is always a choice in legislative bodies between two or more good choices. I am certain that there are committees in this Congress wondering why we are sitting here talking about atom smashers while people are being gunned down in our streets only a couple of miles from here. So, we have to wrestle with all these problems and all these choices.

My only observation, again, is I would welcome, since these choices have to be made, as much advice from the scientific community as is available in how to make the choices, because they are going to come. And I would like to be advised by our best talent in the area in terms of my contribution to that.

Thank you.

Mrs. **Lloyd**. Thank you very much, Mr. Schiff.

And I want to say at this time we certainly do appreciate your participation on this committee. You are a good member, and we are happy to have you on board.

One final question for Dr. Trivelpiece.

I understand that the need for research reactors far outstrips their resources available for these reactors. I would like for you to comment on the material need both at the universities and at our national laboratories as well for these such reactors, our national laboratories for the reactors.

Dr. **Trivelpiece**. Yes. Over the years I have watched with some distress as the concern over nuclear power and nuclear materials and so on has resulted in a diminished availability of certain types of tools for teaching and research. And one of these is reactors.

I was on the faculty at the University of Maryland. Its research reactor disappeared. I have talked to Chuck Young, who is the chancellor at UCLA, and as a result of just the, almost you might say, nuisance value of the paperwork associated with keeping that reactor up, they have shut it down.

The University of California at Berkeley and a number of such facilities have disappeared around the country. And you see increased pressure to continue that trend. And so I look around and ask is there going to be a need for facilities to train people on, using reactors for research being done with them and so on. I come to the conclusion of a resounding yes.

And then you ask where? Well, I think that Oak Ridge is one of the logical places both by historical precedent and by attitude of the area and by the facilities that are there, that it could become in fact, I would say, a campus if you like, at which a number of reactors, of which I would think the ANS would be certainly a flagship where research on structured material could be done and protein crystallography, just a whole collection of neutron scattering and isotope production kinds of things, in addition, a place where students could come and learn how reactors work, how to operate them, utilize them in research and so on, and that that kind of a climate and setting may be an opportunity for us.

And certainly in my new role as the director of the laboratory I would like to work toward that. I think it's important that the Nation maintain an ability to provide neutrons for research and for training in a variety of areas. And thank you for the question.

Mrs. LLOYD. Thank you.

Thank you very much. Thank you, gentlemen, for being with us today.

Panel three includes: Dr. Nicholas Samios, director of Brookhaven National Laboratory; Dr. Fred Morse, associate director of research at Los Alamos National Laboratory, accompanied by Dr. Gerald Garvey, director, Los Alamos National Laboratory—pardon me, he is director of the Meson Physics Facility; and Dr. David Shirley, director of Lawrence Berkeley Laboratory.

Dr. Samios, it is good to have you back with us again.

PANEL 3

STATEMENT OF DR. NICHOLAS P. SAMIOS, DIRECTOR, BROOKHAVEN NATIONAL LABORATORY

Dr. SAMIOS. It's a pleasure to be back.

Mrs. LLOYD. Please proceed with your testimony. As you know, we are running on a tight schedule, but we look forward to hearing from you.

Dr. SAMIOS. Fine. I thank you for the opportunity to once again testify before the Subcommittee on Energy, Research, and Development. This afternoon I will testify on two major areas of our research; namely, general science and basic energy science programs, with particular emphasis on the proposed construction of the Relativistic Heavy Ion Collider at BNL.

The high-energy particle physics program at the alternate gradient synchrotron, AGS, at Brookhaven continues to be vigorous and exciting. We were extremely pleased and delighted that the 1988 Nobel Prize in Physics was awarded to Drs. Lederman, Schwartz, and Steinberger for their work done at this accelerator.

It should be noted that this is the third such award given for experimental research performed at the AGS.

The experimental program discussed on previous occasions involving the search for rare K decays, one part in 10–10, is under way. Four experiments have taken data and sensitivities of this order of magnitude. A few times to 10–10 have been achieved.

In essence, the AGS is demonstrating its role as a very productive accelerator in a high-intensity domain of particle physics. This program, therefore, complements the high-energy capabilities of the TEVATRON at Fermi Lab and the proposed SSC as well as the electron positron experiments performed at Stanford.

On budgetary matters in high-energy physics, we strongly support the DOE fiscal year 1990 budget. This budget is needed for the sustained operation of our facilities and for orderly progress on our capital equipment and construction projects. We are gratified by the continued support for the AGS booster construction project. It is going well, with the final installment of $5 million in the fiscal year 1990 budget.

In the area of nuclear physics, the proposed DOE operating budget for fiscal year 1990 is up 7.9 percent. BNL also receives 7.9-percent increase in its nuclear operating budget from $22.6 million to $24.4 million.

This will allow for sustained and modest expansion of the ongoing program initiated in previous years. This is mainly concerned with the study of the interaction of relatively light ions around the AGS masses of A equals 30, which have been accelerated to 450 GeV.

We again strongly support the DOE nuclear budget. In particular, we are pleased with the increased funding for CEBAF construction project, which is complementary in nature to RHIC.

The basic energy science budgets support two of Brookhaven's national research facilities: the high-flux beam reactor for neutron scattering, and the national synchrotron light source for X-ray on ultraviolet studies of matter. There are approximately 1000 users of these facilities presently at Brookhaven, and we invite the committee to come and see these marvelous facilities at their leisure.

Nearly 70 percent of our BES budget support the operation of these facilities. In past years, there have been heavy budgetary pressures on the operation of these facilities, and we have had considerable difficulty in providing for full operation.

In spite of this, there have been outstanding achievements by researchers using the HFBR and the NSLS. Neutron scattering studies of high-temperature superconductors, for example, carried out at BNL by BNL scientists and their coworkers at MIT, Exxon, and AT&T, have shed light on the origins of this superconductivity.

At the national synchrotron light source, a group from IBM has made a working computer chip with half-micron features using X-ray lithography.

The budget proposed for basic energy sciences for fiscal year 1990 addresses very well the problems we have highlighted in past years and provides adequate funds for full operations. We strongly urge Congress to support this budget.

I now turn to my final topic of this presentation, RHIC, the relativistic heavy ion collider. As you know, R&D funds have been provided by DOE: in fiscal year 1987, $3 million; fiscal year 1988, $6 million; fiscal year 1989, $6.2 million; and proposed fiscal year 1990, $6.5 million.

The project is the most ready project for construction that I know of. That is poor English but that is the only way I know how to put it. You can imagine our surprise and disappointment in the lack of construction funds for this project in 1990.

In this last year, we have successfully constructed and tested two full-scale dipole magnets, two full-scale quadrapole magnets, two sextapole magnets, all of the superconducting variety, and have performed at or above specification.

To reiterate, the physics of this project is exciting. It will produce new forms of matter. The nuclear community, national and international, strongly support the project. NSAC has it as its highest priority, and the Brinkman panel noted it in its report.

DOE strongly supports this project, as well as the ERAP committee of EOE, the energy review advisory board.

Costs have been validated and verified by DOE. Technically, it is ready for construction, and it is cost effective. It would cost twice as much to reproduce this facility anywhere else in the world.

We at BNL are eager and anxious to build and operate such a facility and explore the physics of this new and exciting field. We say let's get on with it.

Thank you.

[The prepared statement of Dr. Samios follows:]

Written Testimony of

Nicholas P. Samios, Director

Brookhaven National Laboratory

before the

Subcommittee on Energy Research and Development

of the

House Science, Space and Technology Committee

February 23, 1989

I thank you for the opportunity to once again testify before this Subcommittee on Energy Research and Development. As you know, Brookhaven National Laboratory is one of DOE's multidisciplinary national laboratories and thus has activities in many fields of science and technology. This afternoon I will testify on two major areas of our research, namely, General Science and Basic Energy Science programs, with particular emphasis on the proposed construction of the Relativistic Heavy Ion Collider (RHIC) at BNL.

The high energy particle physics program at the Alternating Gradient Synchrotron (AGS) at Brookhaven continues to be vigorous and exciting. We were extremely pleased and delighted that the 1988 Nobel prize in physics was awarded to Drs. L. Lederman, M. Schwartz and J. Steinberger for work done at the AGS. It should be noted that this is the third such award given for experimental research performed at the AGS. Quite an achievement! Our user community keeps increasing in size and our external Program Advisory Committee, because of constraints on available running time, must be extremely selective and thus rejects approximately 50% of the proposed experiments. The experimental program, discussed on previous occasions, involving the search for rare decay modes of K mesons (1 part in 10^{10}) is underway. Four experiments have taken data and sensitivities of a few x 10^{-10} have been achieved for several non-allowed decay modes ($K^{\circ}_{L} \rightarrow \mu e$; $K^{+} \rightarrow \pi\mu e$) and hundreds of events have been obtained in rare (10^{-7} - 10^{-8}) allowed modes ($K^{+} \rightarrow \pi^{+} e^{+}e^{-}$; $K^{\circ}_{L} \rightarrow \mu^{+}\mu^{-}$). In essence the AGS is demonstrating its role as a very productive accelerator in the high intensity domain of particle physics. The AGS-

BNL program thus complements the high energy capabilities of the TEVATRON at Fermilab and the proposed SSC as well as the electron-positron experiments at SLAC.

The proposed DOE high energy operating budget for FY'90 is $493M, 12.3% higher than FY'89 with the proposed total high energy budget (operating, capital equipment and construction) of $616M being 10.2% higher than FY'89. We strongly support this increase which is needed for sustained operation of our facilities and for orderly progress on our capital equipment and construction projects. The implications of this budget for BNL are noted in Table I where the operating budget projection for BNL in FY'90 is $66M, 4.5% higher than FY'89. Since this barely keeps up with inflation, this will just allow for the continuation of the present program at the current level, namely 20 weeks of slow beam running at the AGS. This is approximately 10 weeks less than the desired and proposed level of 30 weeks. We have strong support from the high energy and our user community for a higher level and discussions are underway with DOE for additional support of ~ $3M for an increase in running time. We are optimistic that after all the dust has settled on the FY'90 operating budget, more running time will be available for the AGS users.

We are gratified by the continued support for the construction of the AGS booster project. The construction is going well with the bulk of the funding in FY'89, with the final installment of $5M included in the FY'90 budget. For completeness we include the monies received by BNL from the SSC project. It is clear that we are major contributors to the SSC

R&D program both in accelerator and detector areas. As you know, the proposed funding goes from $100M in FY'89 to $250M in FY'90. However, the distribution to BNL has not been decided at this time; therefore for internal purposes, we estimate flat funding.

In the area of nuclear physics the proposed DOE operating budget for FY'90 is up 7.9% for FY'89, $250M versus $190M. Again referring to Table I, BNL has also received a 7.9% increase in its nuclear operating budget from $22.6M to $24.4M. This will sustain and allow for some modest expansion of the ongoing program initiated in previous years. This is mainly concerned with the study of the interaction of relativistic ions centered around the AGS where light ions of mass $A \approx 30$ have been accelerated to an energy of 15 GeV/Amu or 450 GeV. Major experiments have taken data and the planned AGS running time in this light ion mode should increase by about 1 week to 8 weeks. It has been confirmed that maximum stopping of nuclei occurs at the AGS energies. In addition it has been discovered that the ratio of K^+/π^+ increases dramatically with use of heavier nuclei and at large transverse momenta. This operating budget also has an increase for RHIC R&D, $6.6M for FY'90 as planned compared to $6.2M in FY'89. This will now be the fourth year of such R&D funding, FY'87 ($3M), FY'88 ($6M), FY'89 ($6.2M) and now FY'90 ($6.6M). This is the most construction ready project that I know of, yet you can imagine the surprise and yes, the disappointment in the lack of construction funds for this project in FY'90. I will return to this major issue after discussing the Basic Energy Science (BES) program.

The Basic Energy Sciences budgets support two of Brookhaven's national research facilities: the High Flux Beam Reactor (for neutron scattering) and the National Synchrotron Light Source (for x-ray and ultraviolet studies of matter). In addition, BES supports our own internal research programs, including those based at these facilities. Nearly 70% of our BES budgets support the operation of these facilities. About four-fifths of the users come from outside BNL (from universities, industry and other government Laboratories). In past years there have been heavy budgetary pressures on the operation of these facilities, and we have had considerable difficulty in providing for full operations. In spite of this, there have been outstanding achievements by researchers using the HFBR and NSLS. Neutron scattering studies of high temperature superconductors, for example, carried out by BNL scientists and their coworkers at MIT, Exxon and AT&T Bell Laboratories, have shed light on the origins of this superconductivity. At the National Synchrotron Light Source a group from IBM has made a working computer chip with half micron features, using x-ray lithography.

The budget proposed for Basic Energy Sciences for FY 1990 addresses very well the problems we have highlighted in past years and provides adequate funds for full operations. There are, of course, more things that can be accomplished with additional funds, but the proposed FY 1990 budget is a good base to start. We strongly urge Congressional support for this budget. Cut-backs or redistribution of funds by Congress will place us again in the same unhappy situation of past years. Tables II and III summarize the budgetary situation at BNL in this area. One notes a net

9.2% increase in operating funds, the major increases going into BES facility operations, this latter amounting to a 12.2% increase.

We also urge continued strengthening of the research efforts supported by Basic Energy Sciences. These programs address significant long-term scientific problems with the potential for practical application. It is especially important that we not lose sight of research programs that are not highly visible right now. We must, as the BES program tries to do, continue a reasonable level of effort in research on, for example, magnetic properties of matter, or we will give up on the possibility of break-throughs yet to come. We should not forget that many programs in superconductivity were on the verge of being shut down when the discovery of high T_c materials was made.

I now turn to the final topic of my presentation, RHIC, the Relativistic Heavy Ion Collider. As you know, I have kept this Committee abreast of progress on this project in my previous testimony. In effect the R&D program is going well and according to plan. As noted earlier, the initial heavy ion programs at BNL and CERN with light ions and lower energies are underway. There is a user community of over 400 physicists and growing every day. The interest, theoretical and experimental, in this new field of relativistic heavy ion physics as evidenced by publications is growing by leaps and bounds. We now have even greater confidence in our prediction of the formation of the quark-gluon plasma at RHIC energies.

As has been noted many times, the study of relativistic heavy ions is an exciting new field of nuclear physics. It has become so because of advances both in our understanding of the basic constituents of matter, quarks and gluons, and also due to our increased technical abilities to build cost effective accelerators to explore this new domain. We now strongly believe that matter is made of quarks and gluons, and furthermore, that these fundamental particles cannot be isolated in the laboratory but only exist inside a nucleus or nucleon, i.e., they never can become free. However, we want to study their interactions, the dynamics and thermodynamics of quarks and gluons. To accomplish this one needs many quarks and gluons, therefore heavy nuclei A ≈ 200, and further, if one wants them to freely interact, then one requires large nuclear densities, therefore high collision energies. The energy question has been studied in some detail and the consensus is that 200 GeV/Amu, in the center of mass, the RHIC design energy, is a reasonable and conservative value that should produce the required energy densities for quark gluon plasma formation. This is two orders of magnitude (100x) larger than attainable at any present machine and 10x larger than any presently planned accelerator. The interest and participation in the physics is evidenced by: the large and active user programs at BNL and CERN where major experiments are producing interesting data at lower energies with light ions, the increase in the number of conferences and workshops devoted to this subject -- large international conferences now held yearly instead of every other year -- and, of course, the much enhanced number of publications.

The conception of the RHIC project goes back many years with the first serious consideration evidenced by a design developed in 1984. Since then this has been refined several times, emerging with the present cost effective, validated, RHIC design with a five year construction schedule and a FY'90 start. This plan has been supported with an R&D effort beginning in FY'85 and FY'86 with laboratory funds and FY'87 thru FY'89 with DOE R&D funds, including a conclusion by a DOE technical, cost and management review of May 1987 stating "RHIC is ready for construction".

The nuclear and scientific community have consistently supported RHIC from 1983 to the present. This has involved DOE/NSF/NSAC long range planning committees, stating

> "... the United States should proceed with the planning for the construction of this Relativistic Heavy Ion Collider facility expeditiously; and we see it as the highest priority new scientific opportunity within the purview of our science."

Such a facility received similarly strong endorsement in the National Research Council report Physics Through the 1990's (Brinkman Report, January 1986):

> "Two nuclear physics accelerators, of complementary nature, are recommended ... One is an Electron Accelerator ...; the other is a Relativistic Heavy Ion Collider."

In June 1986, the NSAC Subcommittee on New Facilities and National Laboratories addressed specifically the RHIC proposal.

> "The recent development of the field of Relativistic Heavy Ion Physics has further strengthened the very high scientific merit for this project ... RHIC will provide nuclear science in the United

States with a unique world-leading facility with almost unparalleled potential for new discovery."

NSAC has repeatedly reaffirmed RHIC's scientific merit and the importance of a construction start. On a more personal basis, I have had a blue ribbon committee chaired by Professor D. Allan Bromley of Yale, advising me on RHIC for the past four years. Its members are drawn from the major U.S. nuclear national labs and universities as well as distinguished representation from the international community. They have also in their most recent (1989) review confirmed that RHIC is a forefront and unique project that should start construction immediately.

I remind you that the RHIC collider consists of two rings of superconducting magnets capable of accelerating, storing, and bringing into collision two beams each with energies up to 100 GeV/Amu for the heaviest ions. The collider will produce center of mass energies which cover the entire energy range from 14 to 200 GeV/Amu. The energy range is covered without gaps and with sufficient beam intensity to generate thousands of interactions per second, thus permitting the design of extremely sensitive experiments. The collider will have the flexibility of using the full range of ion species, from protons to gold, which will be available from the Tandem/AGS injector complex. With protons, energies of over 250 GeV in each beam will be possible. The capability for collisions between different species will also be provided; for example, gold versus protons would be possible at 100 GeV/Amu in each beam.

The site map is shown in Fig. 1 where the injector (tandem, transfer line, booster), the AGS and RHIC tunnel are displayed. The RHIC ring lattice has 6 arc sections and 6 intersection regions where the beams collide. The superconducting dipole magnets, of which there are 288 in the arcs, are a cold iron design and have a single-layer, cosine-theta coil configuration with 8.0 cm aperture and a yoke length of 9.7 m. The magnets are designed to operate at a field of 3.5 Tesla at a temperature of 4.5K. These are relatively low-field magnets which utilize technology which is well-tested and understood. Most of the physical plant for the collider exists, including an operating helium refrigeration system, and only a modest expenditure is required to complete all the remaining conventional facilities.

It is not appropriate in this testimony to go into any detail on the R&D results; the review committees cited above have done that. However, I should like to remark on the magnet program since it is the single most expensive and difficult part of the project. Since I last spoke to you, we have gone the next step of constructing and testing full length prototype dipole, quadrupole and sextupole magnets. This is in addition to the four full length, full aperture superconducting dipole magnets that performed so well about which I spoke to you last year. The test results of these latest magnets is shown in Fig. 2. The magnetic fields attained in all cases substantially exceed (by ~ 25%) the accelerator requirements. Detailed measurements also verify that the field quality of these magnets also meet machine specifications. We are really in good shape. The immediate plans are for a full cell test and industrial production of magnets.

I conclude by discussing costs; these are noted in Fig. 3. These costs have been verified and deemed reasonable and include costs for experimental detectors as well as contingency. The machine cost is $215M in FY'89 dollars and is spread over a five-year period. We have great confidence in this number due to the numerous in depth reviews and refinements that have taken place since 1984, and furthermore since as I previously noted, approximately half of the project is already in place -- the injectors, tunnel, refrigeration system, etc. Since detector costs are now included in the construction project, we have had many workshops (the latest occurring at BNL this past summer '88) each consisting of over 100 physicists to design prototype experiments and estimate their cost in detail. The detector costs are $73M including contingency in FY'89 dollars. This will allow for equipping four experimental areas to explore the physics at RHIC.

I hope this discussion has brought you up to date on this project. We believe it is a unique, cost effective project, that will be at the cutting edge of nuclear physics. It is ready for construction and we are eager and anxious to build and operate this facility and to derive the expected exciting physics with RHIC.

BNL BUDGETS
(Dollars in Thousands)

PROGRAM	FY 1988	FY 1989	FY 1990	% CHANGE 89 TO 90
HIGH ENERGY PHYSICS				
Operating	57,013	63,179	66,025	4.5%
Capital & Construction	25,390	31,535	24,190	
TOTAL	82,403	94,714	90,215	-4.8%
SUPERCONDUCTING SUPER COLLIDER				
Operating	10,876	14,600	14,600	EST.
Capital & Construction	729	2,947	2,947	EST.
TOTAL	11,605	17,547	17,547	
NUCLEAR PHYSICS				
Operating	21,562	22,593	24,380	7.9%
Capital & Construction	5,780	5,200	4,535	
TOTAL	27,342	27,793	28,915	4.0%

1/89

TABLE I

BASIC ENERGY SCIENCES
BNL OPERATING BUDGET
(Dollars in Thousands)

PROGRAM	FY 1988	FY 1989	FY 1990	% CHANGE 89 TO 90
MATERIALS SCIENCES	34,783	38,800	42,644	9.9%
CHEMICAL SCIENCES	16,245	16,008	17,370	8.5%
ENGINEERING & GEOSCIENCES	39	100	50	-50.0%
ADVANCED ENERGY PROJECTS	50	70	50	-28.6%
ENERGY BIOSCIENCES	1,252	1,140	1,200	5.3%
APPLIED MATHEMATICAL SCIENCES	543	600	600	0.0%
TOTAL BES	52,912	56,718	61,914	9.2%

1/89

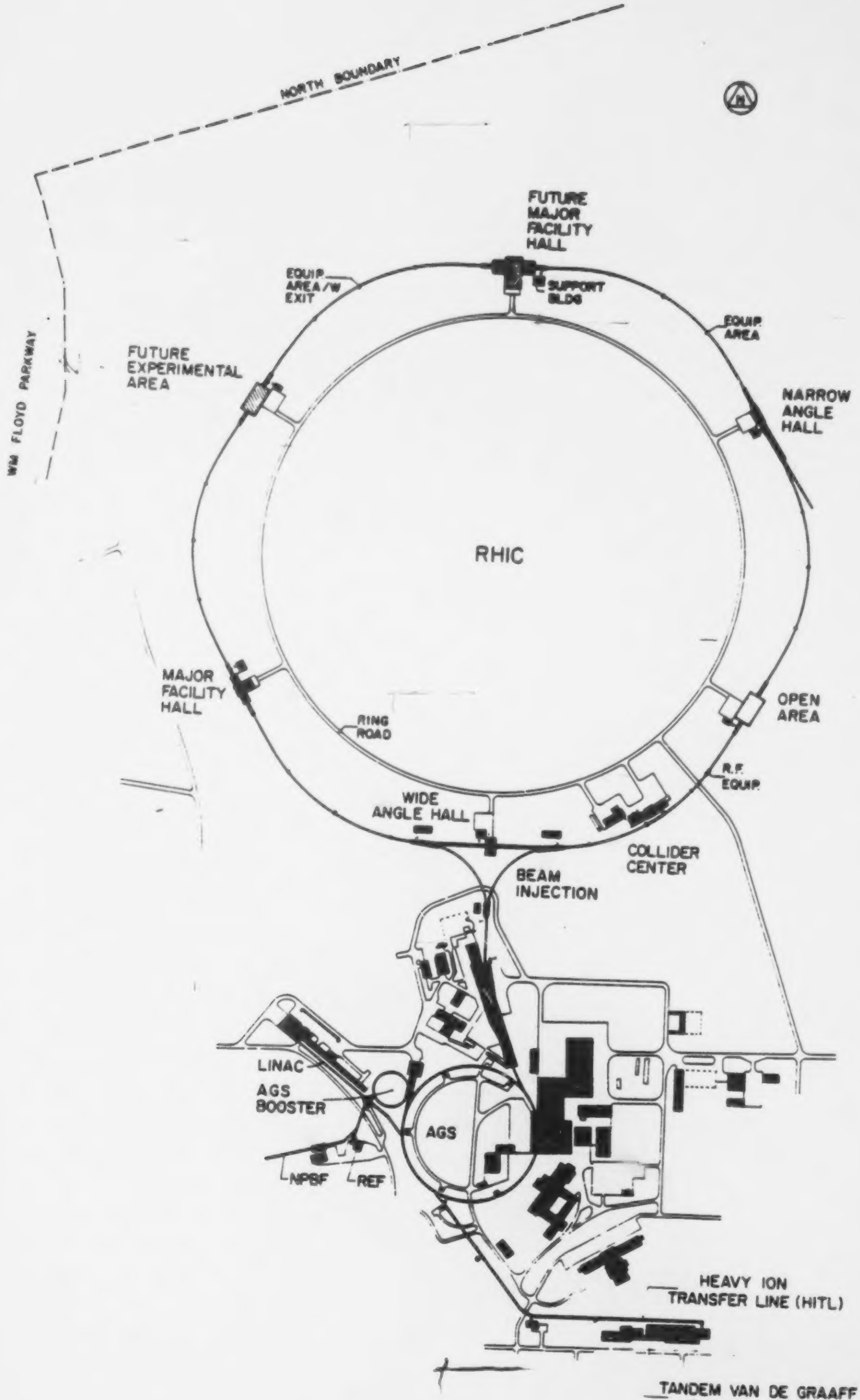
TABLE II

PROGRAM	BASIC ENERGY SCIENCES BNL FACILITIES BUDGET (Dollars in Thousands)		% CHANGE 89 TO 90
	FY 1989	FY 1990	
HFBR OPERATING BUDGET	14,340	15,300	6.7%
NSLS-MATERIALS SCIENCES	13,472	15,465	14.8%
CHEMICAL SCIENCES	5,873	6,885	17.2%
TOTAL NSLS OPERATING BUDGET	19,345	22,350	15.5%
INVENTORY	400	600	50.0%
TOTAL BES FACILITIES BUDGET	34,085	38,250	12.2%

1/89

bnl
aui

TABLE III


NORTH BOUNDARY
WM FLOYD PARKWAY
FUTURE MAJOR FACILITY HALL
EQUIP. AREA/W EXIT
SUPPORT BLDG
EQUIP. AREA
FUTURE EXPERIMENTAL AREA
NARROW ANGLE HALL
RHIC
MAJOR FACILITY HALL
RING ROAD
OPEN AREA
R.F. EQUIP.
WIDE ANGLE HALL
COLLIDER CENTER
BEAM INJECTION
LINAC
AGS BOOSTER
AGS
NPBF
REF
HEAVY ION TRANSFER LINE (HITL)
TANDEM VAN DE GRAAFF HEAVY ION SOURCE

SITE MAP

Fig. 1

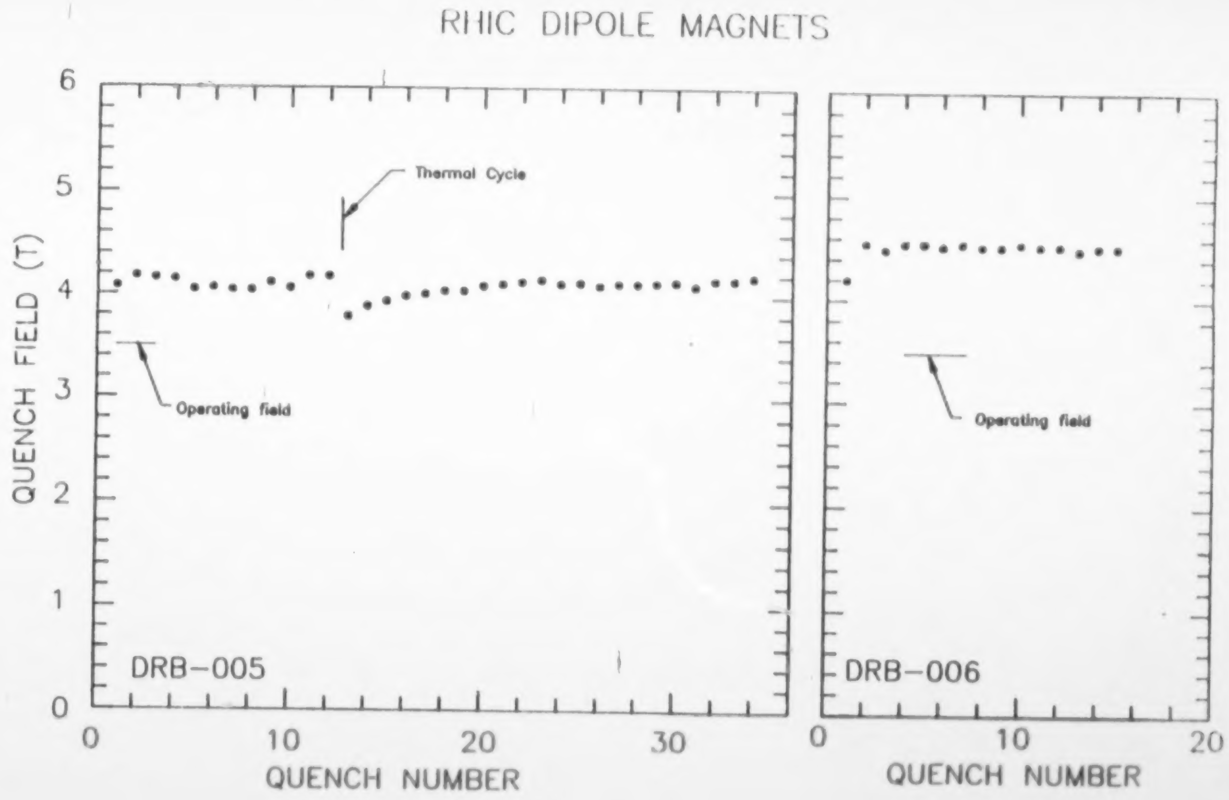
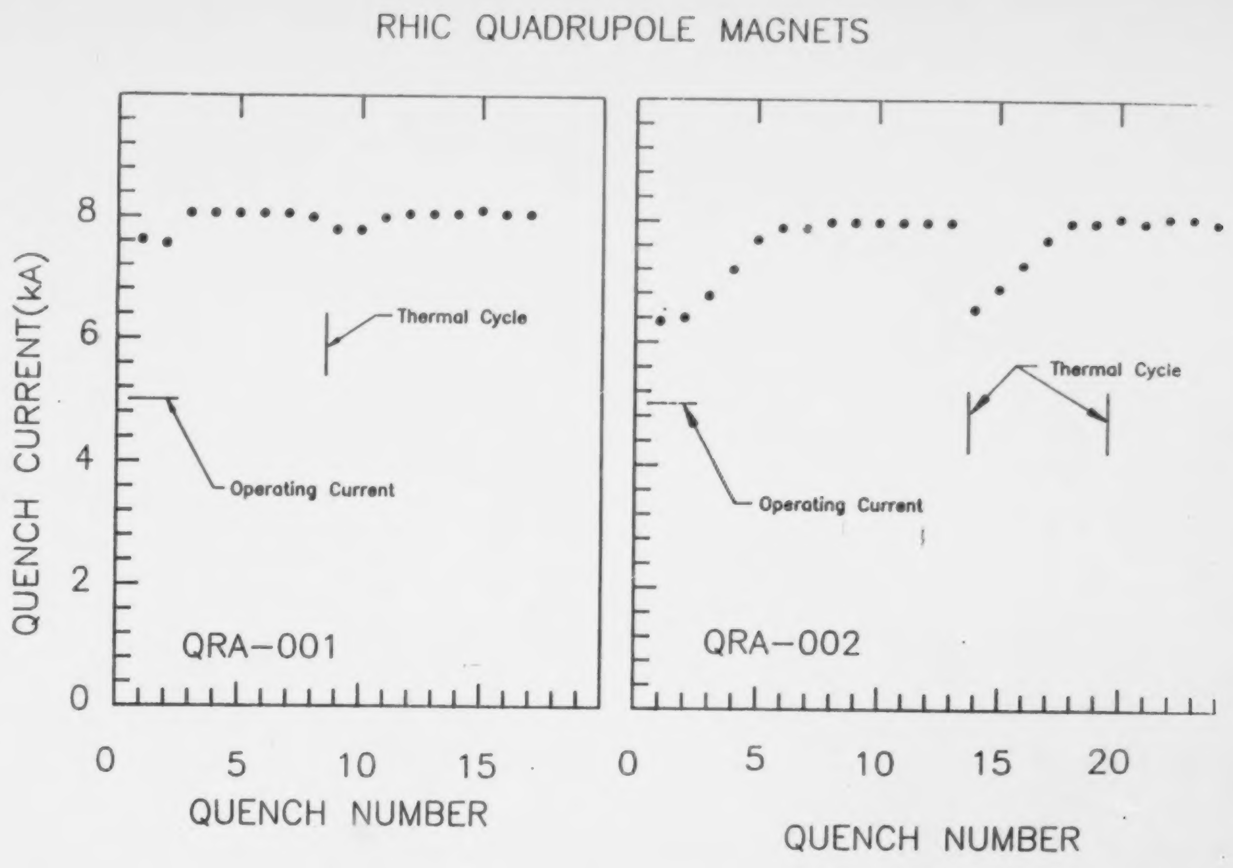

RHIC DIPOLE MAGNETS
QUENCH FIELD (T)
0
1
2
3
4
5
6
Thermal Cycle
Operating field
DRB-005
0
10
20
30
QUENCH NUMBER
Operating field
DRB-006
0
10
20
QUENCH NUMBER

Fig. 2a



SK6087.JH

Fig. 2b

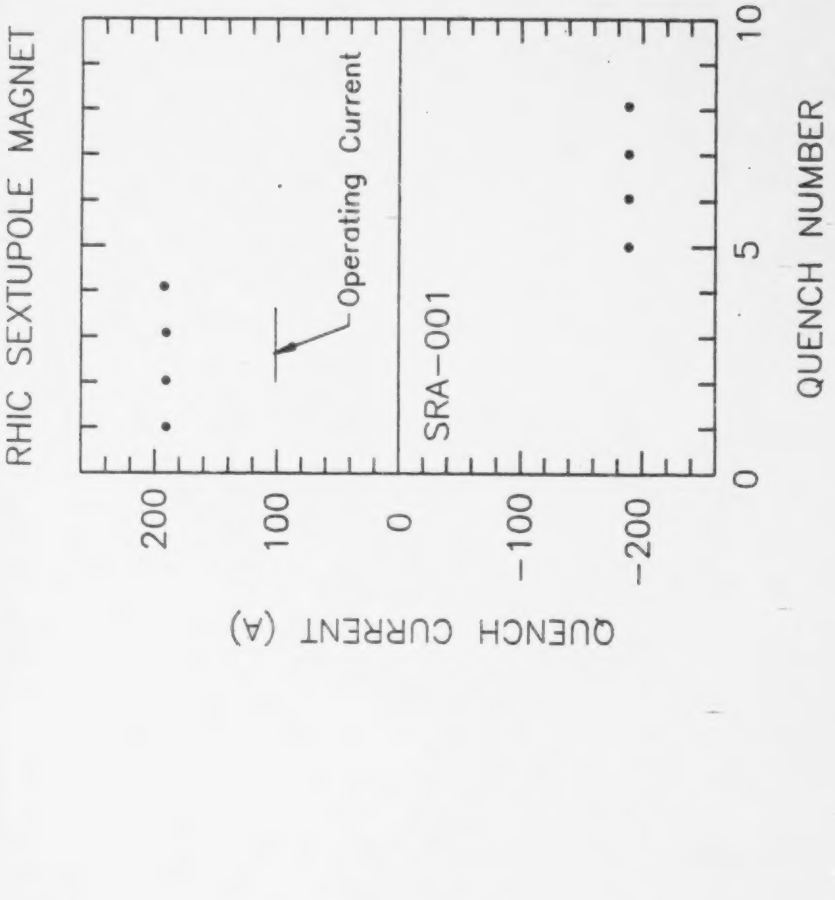


Fig. 2c

SK0018JH

TOTAL PROJECT FUNDING REQUESTED
BY FISCAL YEARS
89$ (1,000,000)

	90	91	92	93	94	TOTAL
RHIC	15	44	64	59	33	215
(MACHINE CONSTRUCTION)						
DETECTORS	-	1	13	30	29	73
	15	45	77	89	62	288
AT YEAR $ PROGRAM (MACHINE & DETECTORS)	15	46	87	109	99	356

FIG. 3

Mr. **Boucher** [presiding]. Thank you very much.

Dr. Morse and Dr. Garvey, I believe you will be testifying together?

STATEMENT OF DR. FRED A. MORSE, ASSOCIATE DIRECTOR FOR RESEARCH, LOS ALAMOS NATIONAL LABORATORY, ACCOMPANIED BY DR. GERALD T. GARVEY, DIRECTOR, CLINTON P. ANDERSON MESON PHYSICS FACILITY, LOS ALAMOS NATIONAL LABORATORY

Dr. **Morse**. That's correct.

Dr. Hecker sends his regards. Dr. Garvey and I hope that we can fill in adequately for him.

I would like my full statement entered into the record. But for now I would like to emphasize just a few points.

Mr. **Boucher**. Without objection, your statement will be made a part of the record, as will the statements of all of the witnesses.

Dr. **Morse**. First, the importance of stable funding for fundamental research just simply cannot be overstated. A very important aspect of the basic energy sciences program is that it funds long-term basic research. I use the superconductor story to emphasize the importance of funding long-term research, not necessarily faddish at the time.

I want to highlight the division of applied mathematical sciences. The DOE mathematics and scientific computing programs are extraordinarily good. I am especially excited about the mathematical science division's Grand Challenges program.

I want to stress the importance of facilities. You have heard a lot about that this morning. I am very pleased by the proposal for a substantial increase in the support of these facilities. Over the last few years the cost of operating facilities has had a terrible impact on the funds for the research. This proposal rectifies that with more nearly adequate funding for operating facilities. My report goes into more detail about even greater needs that could be met.

Lastly, I want to mention the inflation factor. There is an NSAC report which demonstrates the actual cost of doing research in the 1980's period has gone up 7.6 percent per year, and that does not count the extra costs of overhead which have increased because of the extra concerns about security, safety, and the environment, making the total costs go up about 8.5 percent per year while the Consumer Price Index has only gone up 3.7 percent.

In summary, the increased support for facilities is vital. Stability for the core research program is vital. And its size must increase in order even just to match the inflationary costs.

The basic energy sciences program is funding excellent work. It does require long-term stability. Consequently, special needs identified by Congress should be accompanied by adequate funding to add to the program.

[The prepared statement of Dr. Morse follows:]

Statement to the House Committee on Science, Space and Technology Subcommittee on Energy Research and Development

DOE FY90 Budget Request for Basic Energy Sciences
Fred A. Morse
Associate Director for Research
Los Alamos National Laboratory

February 23, 1989

I am pleased to have this opportunity to comment on the DOE FY 90 budget proposal for Basic Energy Sciences and General Science Research.

First of all, I would like to recommend two reports to you that I endorse: a BES Advisory Committee report entitled ***1988 Review of the Basic Energy Sciences Program of the Department of Energy,*** November 1988 (DOE/ER-0395), and a report by a subcommittee of the NSAC, Nuclear Science Advisory Committee, entitled *Inflation Report,* dated February 5, 1988.

The BESAC report argues several times that OBES is well managed, that it is supporting excellent research albeit with inadequate funding. I agree with that assessment. I would like to emphasize a few points to this committee.

IMPORTANCE OF STABLE SUPPORT FOR FUNDAMENTAL RESEARCH

A very important, but too often not appreciated, aspect of OBES is that it funds long-term basic research. It tries to provide stable funding for fundamental work. Of course, it should, and does, respond in a generic way to scientific opportunities and to societal needs by appropriately shifting emphasis on the basic research it funds. It is certainly possible to support fundamental understanding of chemical processes and study many chemical processes of societal interest at the same time, for example. I believe the way in which OBES responded to the exciting discovery of high-temperature superconductors is an excellent example of responsible management. In fact, I would like to use the superconductor story to emphasize the importance of long-term stable funding of research that is not necessarily "faddish" at the time. There were those who regarded superconductivity as a rather moribund research topic. However, important basic work was being accomplished (for example, the heavy fermion research at Los Alamos), and OBES funded it. When the breakthrough came, scientists existed with the expertise and the tools to respond immediately to the new discovery.

I want to single out, for emphasis, the Division of Applied Mathematical Science. The DOE mathematics and scientific computing programs are extraordinarily good, and recently the National Science Foundation properly received positive press because they have established a Science and Technology Center in parallel computing. Note, though, that the Division of Applied Mathematical Science has been supporting essentially this same Center for five years at a level of $8M per year, which is most inadequate for these advanced computing activities. In addition, they are supporting other excellent work in the National Laboratories. I am pleased to say that Los Alamos is one of them. I am especially excited about the Mathematical Science Division's Grand Challenges program through which they entertain proposals from all over the country to do special calculations on fundamental problems in science or engineering with broad applications, whose solutions require large computer resources not normally available to the investigators. Examples of computer intensive grand challenges are: computational fluid dynamics for the design of hypersonic aircraft, efficient automobile bodies, extremely quiet submarines, weather forecasting, efficient recovery of oil. etc. The BESAC report gives many others. I believe this is one area that cries out for more support because the time is right; the motivation, the problems, and the tools are rapidly materializing. At Los Alamos, we are putting together an Advanced Computing Lab, which I describe in an appendix. A revolution is taking place in advanced computation and the environment in which it is taking place. Parallel computing, ultra-high-speed networks, visualization, and distributed supercomputing are just some of the technology-based issues that must be mastered. Our goals with the advanced computational laboratory include providing an open environment for Laboratory, university, and industrial interaction for applications-driven interdisciplinary research involving applied mathematics, computer science and engineering, and experimental technology. We expect to provide computational technology spinoff to industry and solve problems so far beyond our reach.

I want to also emphasize the effect that the declining funding for BES research is having in the Division of Chemical Sciences. There has been little, if any, growth in the areas of chemistry that the National Academy of Science's Pimentel report recommended for emphasis. The cost factors I refer to later have severely hamstrung the Division of Chemical Sciences.

With regard to the Engineering and Geosciences, I have one small reservation with the report pertaining to the suggestion to de-emphasize geothermal sources. However, the major point the committee made regarding research on fluid flow in porous media (rocks and soil) has applications not only to the oil industry, but also to environmental questions of both waste and water. That recommendation is especially important.

Finally, in this section on the importance of the core BES program, I want to emphasize that new, young scientists and engineers are trained at the forefront of our understanding partially owing to the stable DOE funding of important work in universities and at the national laboratories. Their core research program is very important for science today and for the science of tomorrow.

IMPORTANCE OF FACILITIES

I am very pleased by the budget proposal for a substantial increase in the support of facilities. Over the last few years the cost of operating the facilities has had a terrible impact on the funds for research; this proposal rectifies that with more nearly adequate support for operating the facilities.

When the history of the DOE is written for the post-war period, its major contribution to fundamental research may be seen as its support of facilities. No other agency performs this task on such a scale nor so well. Facilities for condensed-matter physics are not big science, but rather a collection of small science projects that all benefit from having a powerful central source, for example, of light (photons) or of neutrons. These facilities have provided an extremely cost-effective way of doing research as measured in cost per paper published. Economies of scale are important; all the ancillary equipment is made available for many, not just the few. The U.S. has not been using its facilities as fully as it could because it has underfunded their operations. My colleague, Dr. Garvey, has made this same point with respect to the nuclear physics facilities. This situation for the Basic Energy Sciences is addressed, to a large extent, by the FY90 budget proposal, and I applaud that. (I have to say that I am trying to convince OBES that some fine tuning is necessary with respect to a net loss for funding for the *Manuel Lujan, Jr., Neutron Scattering Center* at Los Alamos. This loss occurred because OBES used $3.1M as the base for operating funding in FY88 while the actual, and needed, funding was adjusted to $4.8M by the Congress last year.) The BESAC report contains much more detail about the problem of facility support in the past. I will only add that there are many other opportunities that are very important and quite low cost that would benefit the whole BES community. I am sure there are ideas for small-scale facilities at many institutions. For example, at Los Alamos we have an extraordinary Fourier Transform Spectrometer that could be a national user facility with only a small amount of funding. Free electron lasers (FEL) offer the promise of photon fluxes many orders of magnitude in excess of those from existing synchrotron light sources, and about 100 times advantage over the Advanced Light Source. Also, the very short pulses obtained with the FEL permit time resolution measurements that open a whole new area of dynamics in chemistry. Reaction intermediates can be observed that allow mechanisms and energetics to be observed.

A last comment about the cost of facilities: the increased costs associated with environmental protection and safety are often ignored in the allocation process, much to the detriment of the dollars left over to do the research. Unfortunately, not all of these costs mandated by law and regulation make sense. Flexibility needs to be built into these such that we deal with the issue at a specific site, not try to write one regulation to cover everything. The regulations should address the issue and not dictate the means nor the boundary conditions. Real risk assessments must be made and a determination of significant vs. insignificant risk be made.

INFLATION FACTOR

The core research budget request for BES includes a small cost of living factor as an adjustment for inflation. This factor is about 3%. However, I know that 3% is much too small to cover inflation of research costs. My strong personal knowledge from being responsible for the research at Los Alamos is buttressed by the formal study by NSAC to which I referred earlier. They demonstrate that the actual cost of doing research has averaged 7.6% per year from 1981 to 1987 excluding overhead costs. These costs have gone up, too, because of increased costs for security, safety, and environmental concerns (with all of the enormous paperwork costs associated with them) making the actual cost go up by about 8.5% per year. This compares to about 3.7% per year increase in the Consumer Price Index over the same period. The NSAC study did not deal with the increased cost caused by the increasing sophistication of the experiments and, therefore, are only lower limits. This report also attempts to identify the reason for the costs being higher than the CPI. Much of it is due to the fewer number of American scientists coming out of U.S. graduate schools, which results in stiffer competition for staff. It also results in scientific staffs getting older; it is not possible to replenish attrition with young staff. Older, more experienced staff are more expensive than younger ones. Productivity remains high, but our scientists are being stretched thinner every year.

More detail on some of these points can be obtained from the two referenced documents and from the attached appendices.

In summary:

- The increased support for facilities is vital.
- Stability for the core research program is vital, and its size must increase to support at least a constant number of scientists and students—our future.
- OBES is funding excellent work. Special needs identified by the Congress should be accompanied by adequate funding to add to the program.

APPENDIX A
ADVANCED COMPUTING LABORATORY (ACL)

LOS ALAMOS ACL

Computational science has become critical to the performance of the Laboratory's mission, from nuclear weapons design to basic research. Nationally, the importance of scientific computing has also become well recognized. In order to meet grand challenges, a revolution is taking place in advanced computation and in the environment in which it must take place. Parallel computing, ultra-high speed networks, visualization, and distributed supercomputing are just some of the technology-based issues that must be successfully dealt with to realize the potential that we now see clearly. These technological opportunities must be interwoven into the fabric of computational science here at the Laboratory and on a national level.

We are establishing an Advanced Computing Laboratory with the following goals:

- Facilitate Laboratory research in advanced computing (e.g., high-performance computing, high-speed networking, distributed computing, visualization) both through the creation of an experimental laboratory and through catalysis of team-oriented interdisciplinary research.
- Provide a focal point for applications driven, interdisciplinary research involving applied mathematics, computer science and engineering, experimental technology, science and engineering applications.
- Provide an open environment for Laboratory/external interactions and technology transfer (e.g., with universities, industry, vendors, funding agencies) in advanced computing.
- Participate in the development of computational science on a national level, specifically through the DOE Applied Mathematical Sciences Program and the NSF Science and Technology Center in Parallel Computation recently awarded to the consortium of Rice University, Caltech, Argonne National Laboratory, and Los Alamos National Laboratory.

DISCUSSION OF ISSUES

Over the past four decades, the use of computers in science and engineering has given rise to a new branch of science—computational science. The ability to model on a computer what formerly required expensive, hazardous, or simply impossible experiments (e.g., nuclear winter simulations) is one of the major tools in science and engineering today. The effective use of computational models of complex systems has become essential to national security, industrial productivity, *competitiveness vis-a-vis our international trading partners*, and preeminence in science and engineering. Today, we can perform calculations routinely in seconds (on the fastest supercomputers, with modern numerical algorithms) that would have taken centuries using capabilities of only 40 years ago. And yet, these resources are woefully inadequate to meet the grand challenges in science and technology over the next several years.

A number of critical areas in science and engineering require solution by computational means, some requiring orders of magnitude more resources than are presently available. Several lists of grand challenges have been compiled. The Federal Coordinating Committee on Science, Engineering, and Technology (FCCSET) Report, November 1987, *A Research and Development Strategy for High Performance Computing* states:

> "High performance computing technology has also become essential to progress in science and engineering. DOE defines a grand challenge as a fundamental problem in science or engineering, with broad applications, whose solution would be enabled by the application of high performance computing resources that could become available in the near future. Examples of grand challenges are: (1) Computational fluid dynamics for the design of hypersonic aircraft, efficient automobile bodies, and extremely quiet submarines, for weather forecasting for short and long term effects, efficient recovery of oil, and for many other applications; (2) Electronic structure calculations for the design and use of new materials such as chemical catalysts, immunological agents, and superconductors; (3) Plasma dynamics for fusion energy technology and safe and efficient military technology; (4) Calculations to understand the fundamental nature of matter, including quantumchromodynamics and condensed matter theory; (5) Symbolic computations including speech recognition, computer vision, natural language understanding, automated reasoning, and tools for design, manufacturing, and simulation of complex systems."

Very significant advances in the use of serial supercomputers (single processors) have been made over the last 40 years. In a 1984 IEEE article, it was estimated that the speed-up due to hardware improvements and the speed-up due to numerical algorithm improvements have been roughly equivalent, each more than five orders of magnitude! With sufficient, first-class supercomputer resources, many important problems can be solved with today's machines. However, the end of these spectacular improvements is in sight as physical limits imposed by speed of light and heat dissipation make decreases in cycle time for supercomputers more and more difficult. From traditional devices, one might expect another factor of five speed-up at most. There are indications that different technologies may be developed; but, in the near term, a solution to the need for tremendous additional CPU speeds will not be forthcoming.

In February 1987, the Society for Industrial and Applied Mathematics (SIAM) Panel on Research Issues in Large-Scale Computational Science and Engineering called for a National Computing Initiative with the following goals:

"To meet the grand challenges in areas of strategic national importance, the U.S. research community must be able to exploit leading-edge computational technology. This requires, over the next few years, a thousand-fold increase in applied computational performance (i.e., in the range of one trillion floating-point operations, or one teraflop per second, on a sustained basis) and action to ensure innovative applications of this extraordinarily powerful technology."

Parallel computation must be made a practical tool if we are to achieve the performance levels mandated by the grand challenges. For computer scientists and mathematicians, this is a difficult and challenging area of research. Theoretically, speed-up equal to the number of processors cooperating on the same problem is possible; however, new numerical algorithms, new compiler technology, new language constructs or, perhaps entirely new languages, and much more must be developed to realize this enormous potential. Development of new parallel hardware must go hand-in-hand with development of software and numerical algorithms, all of which must be driven by the application for which they are intended. This necessitates a unified, interdisciplinary approach.

The SIAM National Computing Initiative estimates that $1.5B will be required over the next five years to achieve this new level of computational performance:

"The striking commercial and scientific opportunities of modeling with supercomputers mandate that a National High-Performance Computing Initiative be established through the cooperative efforts of federal agencies, universities, and industries. New resources totaling at least $1.5B will be required over the next five years to achieve unprecedented computing power and exploitation of computing technologies in areas of strategic national importance."

In the FCCSET report, the estimate is of the same order of magnitude.

APPENDIX B
MANUAL LUJAN, JR., NEUTRON SCATTERING CENTER
Materials Science Facilities: Issues and Comments

- The British, along with other European Nations, invest in the Institute Laue-Longevin (ILL) primarily as a center for the education of Ph.D.'s in methods of research. Facilities are excellent from this viewpoint for many reasons: they are user friendly, there are experts from different fields of research, etc. If President Bush and the Congress want to be the "education President and Congress," they should strengthen facilities.

- I believe that access to facilities should be made even easier than it is now for users. Many potential users have said they would do experiments at user facilities if they could find a source of travel money. The DOE claims that users can apply for such money in individual grants. This is of no use to the chemist who has just made a new high-temperature superconductor and wants to know its structure *now*, not a year from now. Facilities need budgets to pay travel for users whose experiments have passed peer review.

- The U.S. has not been using its facilities as fully as it could because it has under-funded their operations. This situation is addressed, to a large extent, by the DOE facilities budget for FY90, and the increases DOE has requested are to be applauded. Some fine tuning is necessary, however, in distributing funds between facilities. Manuel Lujan, Jr., Neutron Scattering Center suffered in the FY90 budget because its actual FY89 operating budget was $4.8M whereas DOE used $3.1M as the FY89 base for its FY90 Congressional budget request. The FY90 operating budget for the neutron scattering center needs to be increased by 10% for this reason.

- Even with the planned FY90 budget, some facilities will not run for as long as they could each year. Again, LAMPF and hence the neutron scattering center, are examples.

- In the past few years, DOE has managed to keep its facilities open (but operating under par) by raiding research budgets to pay for facilities operations. This practice must stop, and research budgets must be brought back to an acceptable level.

- This country needs world-class neutron and synchrotron facilities to stay abreast of the rest of the world in condensed matter research, industrial competitiveness, and education.

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- The U.S. needs both the 7 GeV Advanced Photon Source ring and at least one advanced neutron source. It could be argued that it should have both an advanced reactor and an advanced spallation source. We believe an advanced spallation source will be much less costly if built with an Advanced Hadron Facility as we have proposed.

- DOE is pushing a model of industrial collaboration in its facilities in which industry builds instruments at DOE-funded facilities. While there is nothing wrong with this model *per se*, it may not be the best route to improved industrial competitiveness. If the federal government wants to play its part in helping U.S. industry, it should make facilities available to industry as paying customers. This method is a way of using industry to bale out the government's lack of investment in its facilities. In fact, the government should take its proper place in the innovation cycle and provide the instrumentation in most cases. At the very least, an in-depth study of the role of facilities in promoting U.S. industrial competitiveness is required.

- Facilities provide an unparalleled opportunity for scientists from government laboratories, industry and academia to interact. This is an important contribution to industrial competitiveness.

Dr. Garvey will talk about our nuclear physics facility.

Dr. **Garvey**. Mr. Chairman, members of the committee, I welcome this opportunity to briefly present to you the status of the Los Alamos Meson Physics Facility, often referred to as LAMPF.

LAMPF continues to be the world's most intense proton accelerator, with a very active research program, with only ten percent of its capability devoted to LANSCE, the Los Alamos Neutron Scattering Center, it has made that facility a world-class facility.

On July 6 of this year, we are pleased to inform the committee, LANSCE will be renamed the Manuel Lujan, Jr. Center for Neutron Scattering, representing the many contributions of Manuel Lujan to basic research through his effort on this committee.

Now, even though we are losing on the order of about three percent per year to inflation at LAMPF, we continue to carry out a first-rate research program, as has been verified by a very detailed review, some synopses of which I included in my written testimony, that looked at our research over the last six years on a world scale.

Now, losing this three percent per year since 1986—and this appears to carry on into the 1990 budget—I think we have used up now most of the possibilities of increased efficiency and more cost-effective operation. And we are going to be forced to cut back on the breadth of the research program at Los Alamos at LAMPF.

Because of LAMPF's central role to the nuclear physics program of this country, I think it is an issue that we are going to have to pay very careful attention to, and we will carefully monitor our ability to deal with these reductions.

We realize that some cost cuts are necessary in order that we proceed with building CEBAF in an expeditious manner and that we hopefully move into the construction of RHIC as soon as possible.

What I would like to close with is just to discuss with this committee a great opportunity that we have at Los Alamos at the present moment because of the existence of the proton storage ring that allows us to make a very powerful test of the so-called standard model. We can measure the fundamental constant of the electro weak unification, the sine squared of the Wineberg angle, at four orders of magnitude lower energy than it will be measured at the TEVATRON and at the linear collider.

If this number is truly a fundamental constant of nature, then one should observe the same number both at higher energies and at the energies that we can carry out this particular experiment. This will represent either an extraordinarily tight test of the standard model or, if there is good agreement, allows us to apply this electro weak unification with much greater accuracy, about a factor of five times more than we would be able to without this experiment over the whole realm of physical world below 100 GeV.

In order to do this, I think one will have to increment the capital equipment budget in nuclear physics by about $10 million a year. And if I use that analogy of the amount of time that that adds up to in the Federal budget, I think, if I did my arithmetic correctly, that is 24 seconds' worth of Federal expenditure.

Now, this increased capital equipment requirement I think is a thing that is sorely needed in the field. And in fact, I think it is really much overdue. CEBAF and RHIC will put even greater pressure on this equipment budget, and I believe that this large sharing cost detector project at Los Alamos provides an excellent opportunity for us to begin an increase of $10 million in that category.

Thank you.

[The prepared statement of Dr. Garvey follows:]

Statement to the House Committee on Science, Space, & Technology
Subcommittee on Energy Research and Development

DOE FY90 Budget Request for General Science and Research Programs

Gerald T. Garvey
Director
Clinton P. Anderson Meson Physics Facility
Los Alamos National Laboratory

February 23, 1989

I welcome this opportunity to briefly present to this Committee the status of the Los Alamos National Laboratory's Clinton P. Anderson Meson Physics Facility, often referred to as LAMPF. Your continuing interest in basic research plays an essential role in allowing the scientific community to inform Congress on the present state-of-affairs. I would like to extend an invitation to any of the Committee members to visit LAMPF at their convenience to observe first-hand a part of the great return on the nation's investment in our science.

There are three points I would like to make today:

(1) LAMPF continues to be the nation's principal tool for nuclear science. It provides unique research opportunities to the nation's largest group of users in nuclear physics.

(2) At LAMPF there presently exists a unique opportunity to carry out a precision measurement of the fundamental constant of the unified electroweak interaction. Using our upgraded Proton Storage Ring (PSR), in conjunction with a proposed Large Čerenkov Detector (LCD) this precise and important measurement can be carried out in a unique energy regime.

(3) Our plans for a facility upgrade will enable the country to continue advancing the frontiers of nuclear and condensed-matter physics well into the next century.

Since I met with the Committee a year ago, a distinguished review committee was assembled by the Department of Energy to review LAMPF's activities over the past several years within a world perspective. I will discuss the finding of this review and some of their recommendations. They were enthusiastic about the scientific activities at LAMPF, but were concerned about our present level of support and the Department of Energy's plans for our future.

In addition, some of last year's accomplishments and opportunities for new, significant research beginning in 1990 will be presented.

A. The Facility

The heart of LAMPF is a one-half mile long accelerator. It simultaneously accelerates both protons (H^+) and atoms of hydrogen with two electrons (H^-) to energies of 800 million electron volts. By a significant factor, LAMPF has the most powerful beam of any proton accelerator in the world (Fig. 1). The facility is designed to bridge nuclear and subnuclear physics as well as contributing to our understanding of a few carefully selected potential applications. A layout of the LAMPF experimental area is shown in Fig. 2 which illustrates the diversity of particle beams and experiments made possible by the extremely intense primary beam.

The experimental area is designed so that many experiments can be carried out at the same time. A 1-milliampere H^+ beam creates beams of secondary particles (pions and muons) at production targets A-1 and A-2. There are three experimental areas for utilizing pions and one for utilizing muons, which are products of pion decay. The H^+ beam then coasts to the beam stop area where subsequent reactions generate large numbers of neutrinos (neutral elementary particles) that are studied with large sophisticated detection systems.

Simultaneously, two H^- beams are also accelerated and routed to different areas. One goes to the nucleon physics area and another to the Los Alamos Neutron Scattering Center (LANSCE). This facility will be renamed the Manuel Lujan, Jr., Neutron Scattering Center on July 6 of this year. The beam sent to LANSCE represents only 10 percent of LAMPF's capability. It is injected into a proton storage ring to produce intense pulses of neutrons that are primarily used for condensed-matter research. This 10 percent of LAMPF capability is sufficient to render LANSCE a world-class neutron-spallation source.

Another H^- beam, which may be polarized (i.e., the direction of the proton spin can be fixed), is directed into the nucleon-physics area. The capability of this experimental area continues to be upgraded to provide new and unique opportunity to study the nucleon-nucleon and nucleon-nucleus interactions. Thus, there are ten to twenty experiments being carried out simultaneously throughout the LAMPF complex when the accelerator is being operated.

Typically, the accelerator provides beam for research for 3000 hours each fiscal year, although tight funding since 1986 has made this difficult. In the subsequent fiscal years, 1987 through 1989, the pressure of building new facilities elsewhere in the Department of Energy Nuclear Physics program has constrained the LAMPF budget to levels that do not keep pace with inflation. By emphasizing cost-effective measures in both operations and experiment support, we are presently carrying out our highest-priority activities. However, the impacts of these cost reductions are beginning to affect our ability to effectively serve our user community and force us to take gambles that can lead to costly loss of scheduled beam time. These problems are not unique to LAMPF but cut across the entire field where budgets have typically not kept up with inflation since 1986. The vitality and resilience of a field can be eroded by inadequate funding over a several-year period.

As a specific example, the DOE ad hoc review committee referred to above stated *"No laboratory in the world possesses a staff more willing to help users get their experiments done."* They cautioned, however, that the present plan to reduce support at LAMPF *"would have a serious impact on the vitality of the Laboratory . . . and would have a serious impact on the outside user's program."* **Thus, attention must be paid to the issue of reduced funding as LAMPF is the nation's principal facility for the conduct of research in nuclear physics.**

As you might imagine, a facility with such diverse capability has a very large and active group of involved scientists from a variety of external institutions. The statistics of our medium-energy physics user program are shown in Tables I and II. Our users are a vigorous group of scientists from 103 institutions, by far the largest group at any nuclear physics facility in the world.

We are also often able to employ residual portions of the LAMPF beam at no additional cost to our research activity or the taxpayer but with great benefit to the nation. For example, LAMPF allows research at the forefront of condensed-matter science, biology, medicine, and national security to go forward.

In 1987-88 we added to our world-class facilities for the study of nucleon-nucleus interactions by the construction of a 3/8 mile-long neutron time-of-flight (NTOF) path, and a large acceptance medium-resolution magnetic spectrometer. An optically pumped polarized-ion source (OPPIS) is now being installed to increase the intensity of the polarized beams by a factor of 20 to take full advantage of these new facilities. Some 100 researchers are actively planning to use these facilities over the next several years.

B. Present and Near-Term Accomplishments

The LAMPF program today is more vigorous than ever with new, important experiments being put in place.

The LAMPF research program is aimed at increasing understanding of the intrinsic characteristics of the basic interactions among elementary particles—strong and electroweak—and the role played by these interactions in nuclear physics phenomena. The strong interaction is being studied in the nucleon physics laboratory for which the new neutron time-of-flight (NTOF) capability has just been completed. These facilities will allow the study of charge exchange reactions with unprecedented resolution over the entire range of LAMPF energy (200 - 800 million electron volts). In the case of NTOF, a sophisticated detection system allows the researcher to also determine the spin direction of the outgoing neutron. In addition, LAMPF has developed the capability of fixing the spin direction of certain nuclear targets and the intense polarized-ion source (OPPIS) will be brought into operation this year. Thus, scientists should be able to completely specify the spin dependence entering into the interaction. By the mid-1990s, the scientific community should have obtained an excellent characterization of the spin-isospin modes of nuclear excitation as well as the effects of the nuclear medium on the interaction of a nucleon within the nucleus.

The elementary particles and their electroweak and strong interactions have been organized into a single scheme, termed the Standard Model, which is consistent with all available experimental results. However, this model does not include gravity and is not a complete unified description of particle physics. All theoretical attempts to extend the Standard Model predict that new and as yet unobserved phenomena should take place. It is critically important to experimentally test the Standard Model to determine which of the many proposed extensions are correct. Presumably, the correct extension of the Standard Model will indicate how a more unified description of the physical world can be accomplished. Historically, these unifications have had an enormous impact on our view of the world. For example, the electromagnetic unification has significantly impacted our daily lives.

As I indicated to you last year, we are constructing a very sensitive experiment to test the Standard Model. A collaboration involving eleven universities has pooled resources and talent to search for the process in which a muon decays into an electron plus a gamma ray ($\mu \rightarrow e\gamma$) with a sensitivity 500 times greater than previous measurements. This process cannot take place within the context of the Standard Model and experimentally has not been observed to occur at a level of a single event per 200 billion (2×10^{11}) normal muon decays ($\mu \rightarrow e\nu_e\nu_\mu$). However, some extensions of the Standard Model imply that such a decay may, in fact, occur. The principal detector components are still under construction. However, the crucial triggering system has been shown to work according to experimental design (Fig. 3) and we expect to be taking data on this sensitive test of the Standard Model during our 1990 running period.

Neutrino research at LAMPF has been gathering momentum over the past few years. The probability for the scattering of an electron neutrino from an electron has been measured at LAMPF. It shows that the interference between the Z^0 and $W^\pm$ vector bosons, which uniquely enters this process, is destructive as predicted by the Standard Model. This interference is of great importance in a variety of astrophysical phenomena. A sensitive search is being conducted to see if any of the neutrinos created in LAMPF's beam stop can change into an electron antineutrino. This phenomenon, termed neutrino oscillation, is not possible in the Standard Model, but is predicted to occur in many versions of more unified theories. We have as yet found no evidence for this process, but have already reached a level of sensitivity that exceeds previous experiments and our search continues testing the model evermore stringently.

Three years ago it was realized that the short bursts of neutrinos produced by reactions of the beam from the proton storage ring (PSR) would allow a precision measurement of a fundamental quantity, the sine squared of the Weinberg angle ($\sin^2\theta_w$). As a supposedly fundamental constant, it is crucial to the electroweak theory that the value of this quantity be correctly accounted for in a variety of physical processes occurring at vastly different energies. We propose to measure $\sin^2\theta_w$ to better than 1% accuracy. To achieve this accuracy with low-energy neutrinos, a very large detector must be employed. The sensitive material of the proposed detector is 7000 tons of water! A few times a day one of ten million, million, million (10^{19}) neutrinos strikes an electron bound to one of the water atoms. The recoiling electron radiates Čerenkov light that is detected in some of the 13,000 phototubes that view the large volume of the water. The experiment is referred to as LCD, for Large Čerenkov Detector. A schematic diagram of the neutrino source and the detector is shown in Fig. 4. The proposal for this multimillion-dollar experiment has been reviewed for scientific and technical merit by external peer review committees convened by DOE and is very strongly endorsed. The detailed costs and schedules have also been reviewed and verified. As no action has yet been taken, the project is still under review and prioritization by NSAC. The LCD experiment is the highest priority undertaking at LAMPF. However, we cannot start assembling the experiment without approval to proceed. It has been recognized by all scientific reviewers that it is essential to proceed with LCD in a timely fashion. We are ready to go and believe that the LCD experiment should be authorized and that the necessary supplemental funds should be added to the Nuclear Physics capital equipment budget. To fund LCD, incremental capital equipment funds need to be added to this budget category. The present $20.0 M request by DOE is inadequate to respond to the scientific opportunities in our field. A more appropriate level would be $30.0 M per year. Funding LCD would greatly increase the scientific productivity of LAMPF over the next several years.

As an example of applications-oriented research, a collaboration involving Brigham Young University, Idaho National Engineering Laboratory, and Los Alamos has been studying the reaction sequence in which a negatively charged muon is captured in a $d-t$ molecule. The muon acts like a heavy electron and serves to cancel the repulsive Coulomb field between the $d-t$ nuclei. Thus, the d and t can get close together and fusion occurs generating an alpha particle and a neutron with a 17-million-electron-volt energy release. Although the muon lives only two-millionths (2×10^{-6}) of a second, it has been observed at LAMPF that, under appropriate conditions, each muon can be made to cause an average of 150 fusions before decaying. This number is appreciably more than expected, and further research is being invested in understanding the limits to this remarkable phenomenon. Others at Los Alamos and elsewhere are investigating the possible use of this process in an actual energy generation system.

After studying the extent and quality of the achievements and ongoing work at LAMPF, the DOE Review Committee responded to its *Charge* with the following statement.

> *"Generally speaking, the Laboratory has succeeded in building a strong, balanced, physics program that has been sensibly focussed on the unique capabilities of LAMPF. In our view, LAMPF is a world leader in medium energy pure and applied physics. Such things do not occur by accident, and we would like to commend the management of LAMPF on their success."*

LAMPF provides 10% of its beam to LANSCE which in turn provides the U.S. materials-science community with a world-class pulsed-neutron source in a cost-effective manner. The Congress and the Basic Energy Sciences program in DOE have provided $17 million to construct a new experimental hall, which has been completed. It will allow effective use of this capability, particularly in the area of condensed-matter physics. In addition, the LAMPF beam is used to produce radioisotopes for medical pharmaceuticals and other applications.

C. The Distant Future

In the more distant future, I am convinced that the U.S. nuclear physics community will require access to a *high-intensity proton facility* with energies 100 times that now available at LAMPF. Such a world-class facility has been referred to as an *advanced hadron facility*. The need for an ad-

vanced hadron facility is driven by two scientific thrusts. The first is understanding the implications of quantum chromodynamics (QCD) for the world of hadrons. Hadrons, such as protons, neutrons, kaons, and antiprotons, are the physical manifestations of quarks (the elementary particles that undergo strong reactions). The QCD theory, while likely the correct theory of strong interactions, is notoriously difficult to implement on the length scale where particles observed in the real world actually occur. The difficulty is specifically associated with the manner in which the "color" (analogous to charge in electromagnetic interactions) of quantum chromodynamics is actually confined to the hadronic interior. Further, we do not have a great deal of knowledge regarding the kinds of "colorless" objects that can be formed out of quarks and gluons, the elementary objects of QCD. For example, can two pieces of "glue" be put together to form an observable particle.

The second major research area for an *advanced hadron facility* is the careful study of the properties of the copious numbers of weakly decaying particles and neutrinos that will be produced. Precise study of these particles and neutrinos may reveal the way in which the present-day Standard Model will have to be extended if a theory of all fundamental physical processes is to be developed. In this latter sense, the research is complementary to the Superconducting Super Collider project.

A long-range plan for the U.S. basic research program in nuclear physics was formulated in 1983. This plan assumed the Continuous Electron Beam Accelerator Facility (CEBAF) that had been selected in the spring of 1983 would proceed to construction in an expeditious manner. The 1983 plan, thereupon, stated that the highest priority for additional construction was to provide a large increase in the energy of heavy ions via a collider being proposed in the form of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. We are now addressing the FY90 budget with RHIC not yet submitted to Congress for authorization and with the delays in the implementation of that 1983 long-range plan painfully evident to all parties. It is not clear when the fiscal pressures that presently constrain federal expenditures will abate. Large and scientifically important projects, such as the SSC, further impact the available resources and engender even greater uncertainty as to the rate at which the legitimate scientific needs and opportunities in other scientific fields will be met. The distress caused by the resulting very long delays envelops both the scientists whose contributions and careers depend on these new facilities and the laboratories charged with designing, building, and operating these high-priority facilities on far from optimal schedules. Additionally, it affects those parts of the scientific community who see additional facilities required for a sound scientific future. For example, while the need for a sizable increase in energy of the high-intensity proton facilities has become evident, we at Los Alamos with the best existing injector for such a facility have not even had the opportunity to formally propose construction of such a facility.

As you are probably aware, LAMPF plays a vital role in the technical and intellectual life of Los Alamos National Laboratory. Through its users program LAMPF is a major link to the outside scientific community and provides both a base and source of people and hardware that has spawned many activities throughout the Laboratory. The health of LAMPF is an important element in the overall capability of the Laboratory to carry out its national security mission. The Laboratory must evolve scientifically to ensure the nation's nuclear deterrent in a world of hopefully reduced numbers of weapons, while broadening its role in conventional defense technology. First-class, basic-research facilities will continue to be crucial in enhancing scientific vitality.

In light of present fiscal realities, a major upgrade of LAMPF appears difficult to plan for during the next several years. Therefore, it is essential that a set of phased, smaller upgrades at LAMPF be undertaken to keep our research at a world-class level. Authorization of the LCD experiment would be a major step in this direction.

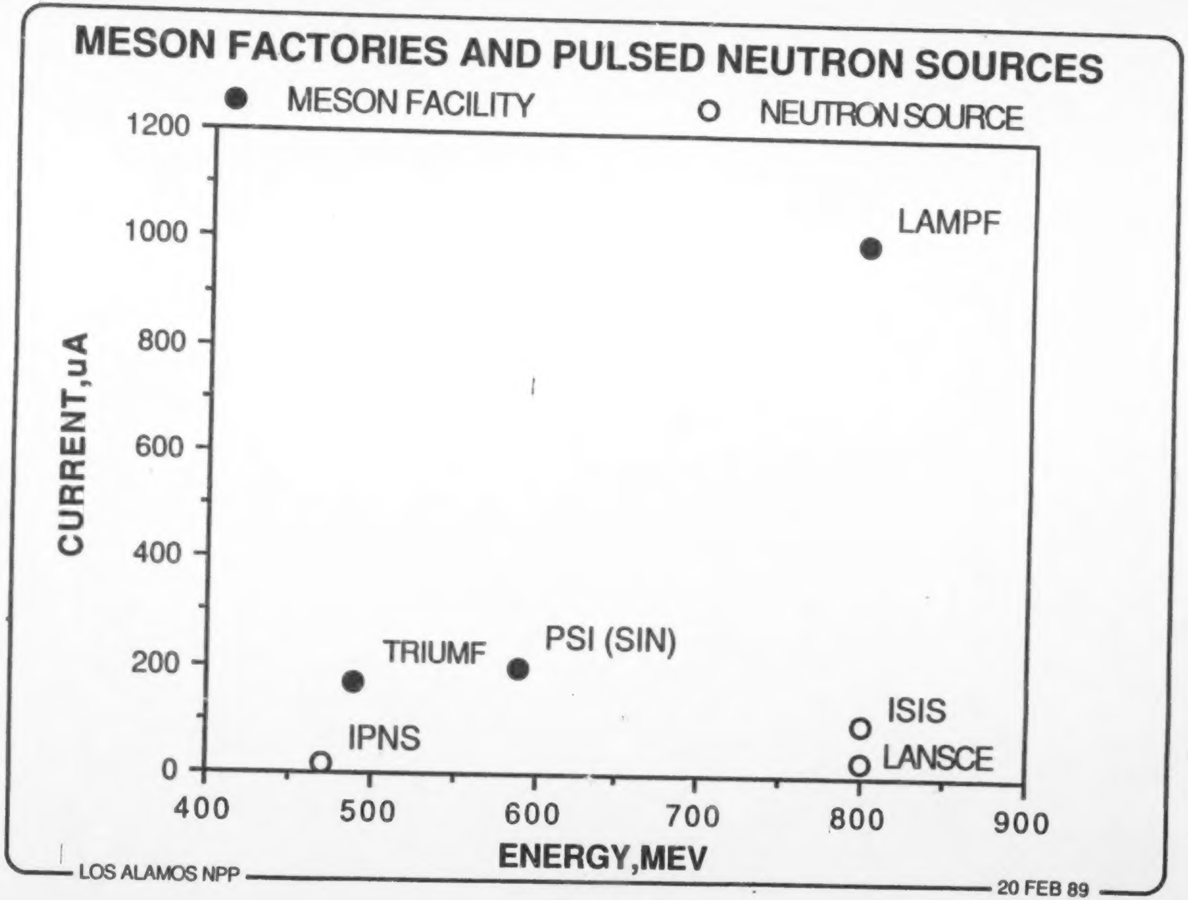
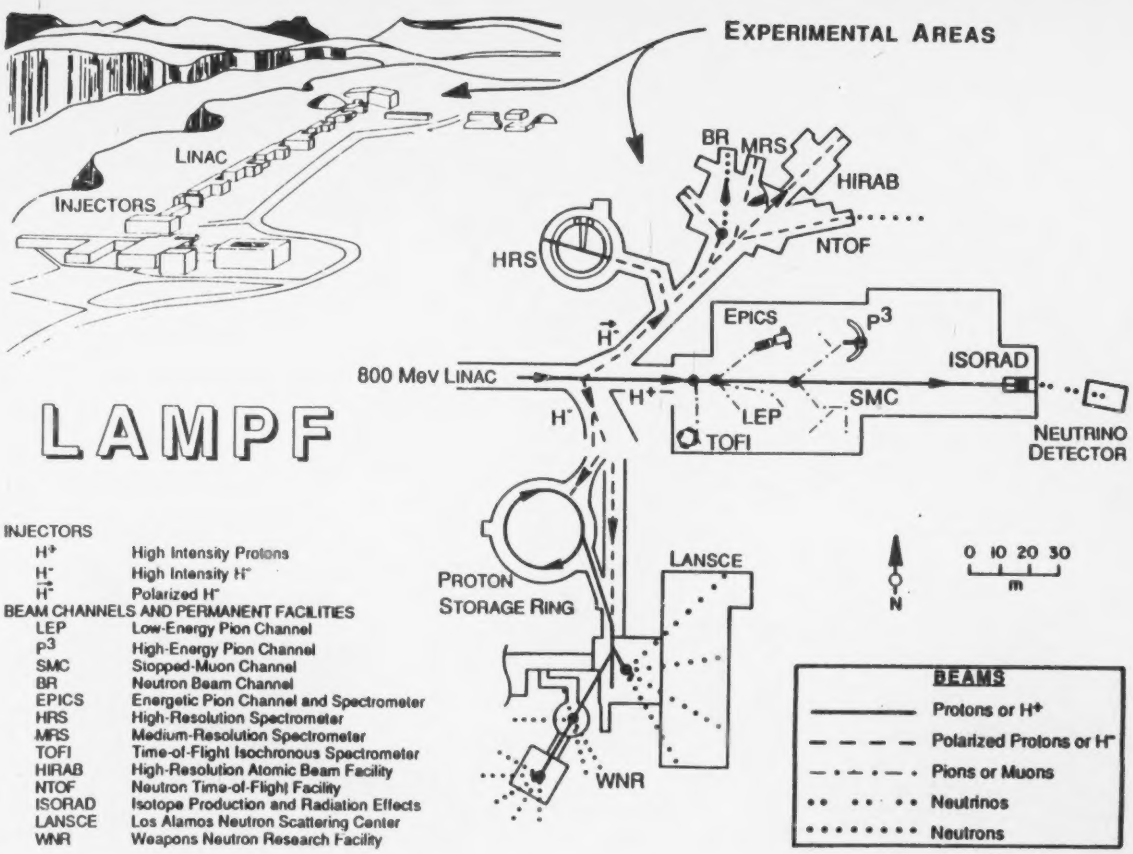

MESON FACTORIES AND PULSED NEUTRON SOURCES
● MESON FACILITY
○ NEUTRON SOURCE
CURRENT,uA
1200
1000
800
600
400
200
0
400
500
600
700
800
900
ENERGY,MEV
LAMPF
TRIUMF
PSI (SIN)
IPNS
ISIS
LANSCE
LOS ALAMOS NPP
20 FEB 89

FIGURE 1


EXPERIMENTAL AREAS
LINAC
INJECTORS
BR
MRS
HIRAB
NTOF
HRS
EPICS
P^3
ISORAD
$\vec{H}^-$
800 Mev LINAC
H^+
H^-
LEP
SMC
TOFI
NEUTRINO DETECTOR
LAMPF
PROTON STORAGE RING
LANSCE
WNR
N
0 10 20 30
m
BEAMS
Protons or H+
Polarized Protons or H-
Pions or Muons
Neutrinos
Neutrons

INJECTORS

H^+	High Intensity Protons
H^-	High Intensity H^-
$\vec{H}^-$	Polarized H^-

BEAM CHANNELS AND PERMANENT FACILITIES

LEP	Low-Energy Pion Channel
P^3	High-Energy Pion Channel
SMC	Stopped-Muon Channel
BR	Neutron Beam Channel
EPICS	Energetic Pion Channel and Spectrometer
HRS	High-Resolution Spectrometer
MRS	Medium-Resolution Spectrometer
TOFI	Time-of-Flight Isochronous Spectrometer
HIRAB	High-Resolution Atomic Beam Facility
NTOF	Neutron Time-of-Flight Facility
ISORAD	Isotope Production and Radiation Effects
LANSCE	Los Alamos Neutron Scattering Center
WNR	Weapons Neutron Research Facility

FIGURE 2

LAMPF USER STATISTICS
END OF 1988
Nuclear Physics

45	Experiments Received Beam in 1988
286	Scientists Participated in 1988
103	Experiments in Active Status
487	Participants in Active Experiments
103	Institutions Represented (23 Foreign)
1165	Proposals Submitted since 1971
633	Experiments Completed
135	Ph.D.'s Based on LAMPF Research
996	Members of LAMPF Users Group

TABLE I

LAMPF BEAM USAGE IN 1988

LAMPF RESEARCH PROGRAM	
Number of Experiments	45
Number of Participating Scientists	286
LOS ALAMOS NEUTRON SCATTERING CENTER	
Number of Experiments	84
Number of Participating Scientists	75
WEAPONS NEUTRON RESEARCH	
Number of Experiments	19
Number of Participating Scientists	69
NEUTRAL PARTICLE BEAM PROGRAM	
Number of Experiments	1
Number of Participating Scientists	10
ISOTOPE PRODUCTION PROGRAM	
Number of Isotopes	20
Number of Shipments	157
Number of Receiving Institutions	68

TABLE II

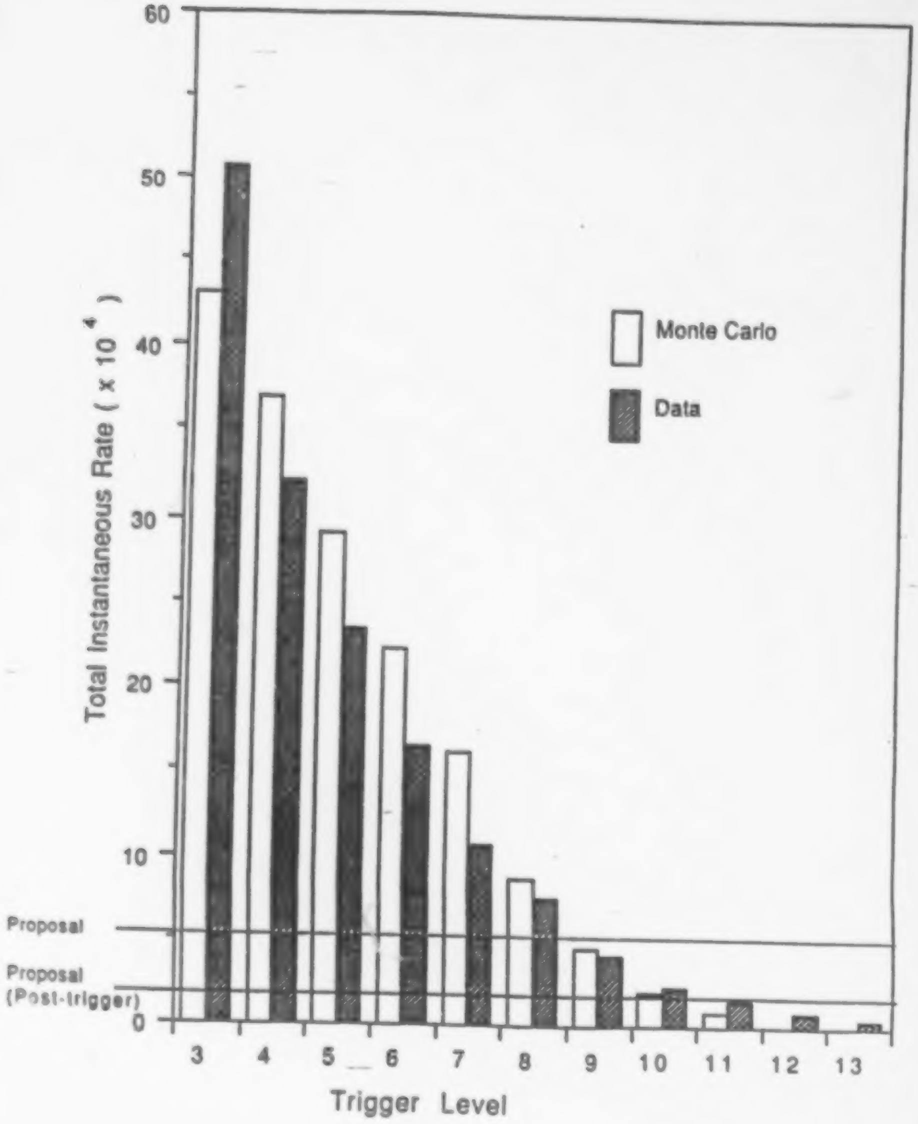
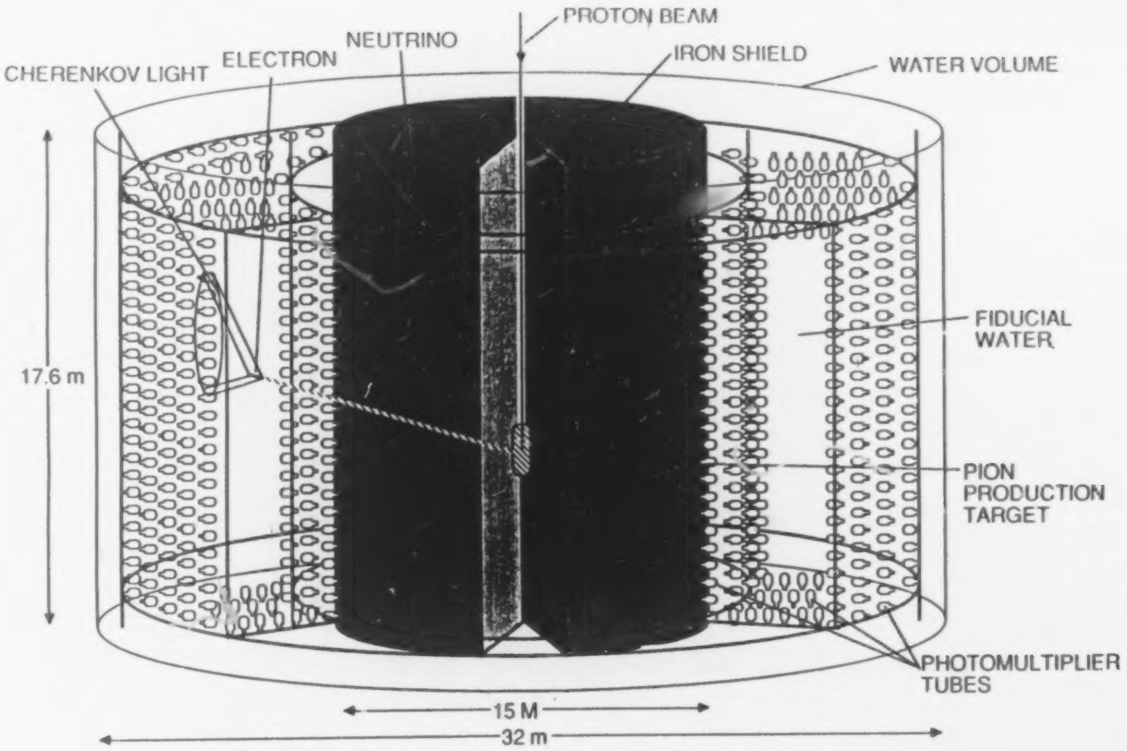

60
50
40
30
20
10
0
Total Instantaneous Rate (x 10^4)
Monte Carlo
Data
Proposal
Proposal
(Post-trigger)
3
4
5
6
7
8
9
10
11
12
13
Trigger Level

FIGURE 3


PROTON BEAM
NEUTRINO
IRON SHIELD
ELECTRON
CHERENKOV LIGHT
WATER VOLUME
17.6 m
FIDUCIAL WATER
PION PRODUCTION TARGET
PHOTOMULTIPLIER TUBES
15 M
32 m

LARGE CHERENKOV DETECTOR

Los Alamos National Laboratory
V. Sandberg January 1989

FIGURE 1

Mr. BOUCHER. Thank you, Dr. Garvey.

Dr. Shirley?

STATEMENT OF DR. DAVID A. SHIRLEY, DIRECTOR, LAWRENCE BERKELEY LABORATORY

Dr. SHIRLEY. Thank you. Mr. Chairman, members of the subcommittee, I am pleased to begin my testimony by describing two recent exciting scientific discoveries in which the Lawrence Berkeley Laboratory has played a major role. Both utilized the unique capabilities of multiprogram national laboratories supported by the Basic Energy Sciences Program and the General Sciences Program within the office of energy research.

To illustrate the first, late last year LBL researchers, in collaboration with Lawrence Livermore National Laboratory, used a scanning tunneling microscope developed at LBL's Center for Advanced Materials to take the first-ever picture of an unaltered DNA double helix, which you can see in this picture which I would be pleased to pass around if you would like to take a closer look.

Even more recent is the discovery last month by scientists from LBL, from Los Alamos Laboratory, and the Mount Wilson Los Campanos Observatory of a pulsar within the 1987 supernova. A key ingredient of this investigation was the laboratory's astrophysics group, supported by both the general sciences and the Basic Energy Sciences programs.

At this point, with the Chair's permission, I would like to request that a copy of my written statement and our annual report be inserted in the record.

Mr. BOUCHER. Without objection, it will be inserted.

Dr. SHIRLEY. Today's hearing is of central importance to LBL, which is funded by all five Basic Energy Sciences programs as well as by the General Sciences program. We at LBL view the proposed growth in this year's DOE research budget as a positive sign of our national commitment to the basic research which will, in large measure, drive our economic future.

Many of the results of this basic research will come from the exploitation of scientific facilities to be built and operated by the Department of Energy. The first of these facilities now under construction is the 1-to-2-GeV synchrotron source, also known as the Advanced Light Source at LBL.

Especially critical to these facilities is preoperations R&D. As the facilities are being constructed, work is done to optimize the technological components. This support is essential to ensure that the facilities will operate at the scientific frontier from the beginning.

With the completion of the Advanced Light Source on the horizon we are already planning to provide the best and most efficient operating environment for our users. An adequate operating budget will be essential for this.

We are, therefore, especially pleased to see the proposed increase for facilities support in the fiscal 1990 basic energy sciences budget request.

The Lawrence Berkeley Laboratory has developed two diverse research initiatives to take advantage of the advanced light source. The first of these is the LBL Center for Chemical Dynamics. This new center would couple the advanced light source with the user-dedicated infrared free-electron laser for studying the interaction of radiation with matter at the molecular level. Led by Dr. Yuan Lee, winner of the 1986 Nobel Prize in Chemistry, the center would provide fundamental knowledge of combustion and other basic chemical processes.

The second initiatives is the Advanced Light Source Life Sciences Center. The unique brightness of the light source beams will provide biologists with submicroscopic images of biological systems in their natural state for the first time. This technology is in its infancy, but completion of the Advanced Light Source will facilitate higher resolution imaging of these systems, telling us more than ever about the living world.

The Advanced Light Source, the complementary Advanced Photon Source at Argonne, and the Advanced Neutron Source for Oak Ridge are proposed to be funded through the Basic Energy Sciences budget. Their usefulness, however, will extend to many other research programs, including those funded by the National Science Foundation, NIH, and DOD, for which we must not forget that DOE carries the entire burden of operating national facilities.

This committee is to be congratulated for the support it has given DOE in the advancement of the Nation's scientific and technological base. You have realized that the strength of American science rests on our unique interlocking system of universities, industries, and national laboratories. During the 1980s our national labs have been revitalized. Their missions have been strengthened by renewed DOE support and by the designation of new national user facilities, including the ones I have just mentioned.

The department deserves credit for recognizing and supporting these new initiatives, but your help is also needed to assure that the critical role of our national laboratories and basic scientific research is maintained, strengthened, and recognized.

As Congressman Mineta has so kindly noted, I will be stepping down as the fourth director of LBL at the end of June. It has been an honor and a privilege to guide this laboratory over the past nine years. We at LBL have been proud to contribute our scientific creativity to the Nation in support of national scientific and technological goals.

When I took over the reins in 1980, I inherited a laboratory with a great past. With the strong support of this committee and the Department of Energy, I am confident that I am leaving a laboratory with a great future.

I would be pleased to answer questions.

[The prepared statement of Dr. Shirley follows:]

Written Testimony of David A. Shirley
Director, Lawrence Berkeley Laboratory
House Science, Space and Technology Committee
Subcommittee on Energy Research and Development
February 23, 1989

Madam Chairman and Members of the Subcommittee, it is a pleasure to be here today to describe for the Committee the scientific programs at the Lawrence Berkeley Laboratory and how they contribute to the national research and development effort. I will provide a brief overview of the Laboratory and the impact of the Department of Energy's Fiscal Year 1990 budget proposal on our research efforts, with a special emphasis on the Basic Energy Sciences program. I will conclude with a few words on the future of the Laboratory.

Lawrence Berkeley Laboratory is a national laboratory managed for the Department of Energy by the University of California. As a multiprogram laboratory, its programs have been designed to meet national needs in energy and technology innovation. The Laboratory has also had a major role in the development and operation of national user facilities to support DOE's scientific programs. A unique relationship with, and proximity to, the University of California, Berkeley campus provides the opportunity for numerous collaborations with faculty scientists that greatly enhance the scientific output of our programs. As the universities and national laboratories become more involved in working with industry, the LBL-UC Berkeley connection is an attractive draw for industrial collaboration. Our relationship with the University has also created a special environment in which we provide strong support for education of the next generation of scientists and science educators.

The subject of today's hearing is of central importance to LBL. LBL is the only national laboratory with major research funded by all five programs within the Basic Energy Sciences program (BES), as well as the General

Sciences programs. With this perspective, we view future growth in this year's DOE research budget, along with the growth in previous years, as a positive sign of our nation's commitment to the basic research which will drive, in large measure, our national economic future.

BES and the Scientific Facilities Initiative

Many of these results will come from the exploitation of a proposed set of new scientific facilities to be built and operated by the Department of Energy. Conceived to meet DOE goals, these facilities were also designed for the use of the entire national scientific community. In its FY 1987 budget, responding to the recommendations of the scientific community and the needs of DOE programs, the Department proposed a Scientific Facilities Initiative consisting of four major new national user facilities. This initiative moved forward largely through the work of my colleague Al Trivelpiece, now the director of Oak Ridge National Laboratory. Each of these facilities was assigned to a different national laboratory, and each will strengthen its laboratory's missions in scientific areas important to the Department. Equally significant, these facilities will be centers of collaboration among scientists from the laboratories, universities and industry. BES will construct and operate three of these facilities.

I am pleased to report that the first of these facilities to be built is the 1-2 GeV Synchrotron Source, or the Advanced Light Source, at LBL. Construction of the ALS began in Fiscal Year 1987, and is actively underway today. The FY 1990 budget requests $26 million to continue the project. Although $30 million was requested in FY 1989, only $25 million was appropriated, without prejudice towards the project. The Department plans to restore the $5 million in its FY 1991 budget request, but this delay in funding will have an impact on the project's cost and completion date. The total estimated cost as reflected in this year's budget submission has increased from $98.7 million to $99.5 million. This additional $800,000 is the inflationary impact of the funding delay. Unfortunately, the construction project data sheet is incorrect in showing the project completion in the 2nd quarter of FY 1992. The correct completion date before the budget reduction was the 4th quarter of FY 1992, and the postponed funding has moved that date back to the 2nd quarter of FY 1993.

As LBL moved through the pre-construction R&D and initial construction of the Advanced Light Source, we found it extremely important to consult the potential users of the proposed facility on a regular basis. Their input into the design and operation of the facility has helped to create a "user-friendly" machine where the scientific community can produce the best scientific results possible. Since 1984, an ALS Users Executive Committee, comprised of researchers from both inside and outside LBL, has advised me on the development of the facility. In addition, an ALS Users Meeting held in Berkeley last year was attended by more than 300 scientists from around the country. They are already submitting proposals for research projects at the ALS, eagerly anticipating the arrival of the first photon beam in 1993. Especially critical to projects underway, like the ALS, is what is called pre-operation R&D. As these large, complex facilities are under construction, many state-of-the-art technological components are altered to fit the realities of construction and optimize the machine's operation. Such changes permit users' recommendations to be accommodated into the machine and its instrumentation as early as possible. This R&D support during construction is critical in assuring that these facilities will operate at the scientific frontier from the beginning.

With the completion of the ALS on the horizon, we have already begun to turn our attention to providing the best and most efficient operating environment for our users. An adequate operating budget is the only answer. This has been a concern at many DOE facilities, both in BES and other DOE programs. At earlier hearings, you have heard LBL testify about the Bevalac, our heavy ion nuclear physics facility. Since 1984, constant dollar operating budgets have resulted in reduced operating hours and services for Bevalac users. Because of this experience, we are especially pleased to see the proposed increase for facilities support in the FY 1990 BES budget request.

After ALS construction is finished, there will be a continuing need for adopting technological innovations to the facility. Operation of these machines means more than providing electrical power and a clean place to work. Maintaining these facilities in the forefront of their fields will require continuing development of accelerator technology and scientific instrumentation for new scientific applications. The High Energy Physics program in DOE has been particularly supportive of this work, both in facility operating budgets and in specific support for technology development related to their facilities. As BES begins to support accelerator-based facilities, it is incumbent upon them to invest not only in the research but in the development of the facility technology itself.

The Advanced Light Source, the complementary Advanced Photon Source at Argonne National Laboratory, and the Advanced Neutron Reactor proposed for Oak Ridge are being funded through the Materials Science portion of the BES budget. Their usefulness, however, will stretch well beyond the confines of this program into many of the BES and Energy Research programs. The decision to build these facilities was made after reviews by a broad spectrum of the scientific community, and the research opportunities they present are not limited to materials science. Their availability could be exploited by many different DOE science and technology programs. Let me provide the Committee two specific examples of research proposals that have been developed by LBL to take advantage of the Advanced Light Source.

The first of these is the LBL Center for Chemical Dynamics that has been proposed to the Chemical Sciences division of BES. This new Center would couple the ALS with a user-dedicated infrared free electron laser for studying the interaction of radiation with matter at the molecular level. The Center would take advantage of a strong LBL-UC Berkeley nucleus of scientists to establish a user facility for visiting scientists from around the nation. Led by Dr. Yuan Lee, LBL scientist, UC Berkeley professor and winner of the 1986 Nobel Prize in Chemistry, the Center for Chemical Dynamics would provide fundamental knowledge of basic chemical processes underlying combustion, atmospheric chemistry and energy storage.

The second initiative based on the ALS is the Life Sciences Center which has been proposed to the Office of Health and Environmental Research (OHER). Taking advantage of the unique brightness of the ALS beams, biologists are working with physicists, chemists and engineers to establish the first dedicated biological facility at a light source in the United States. Of particular need for biologists is the ability to prepare, characterize and measure delicate and often transitory samples close to the experimental station. The ALS Life Sciences Center will provide the necessary space, and the technical assistance, for biologists to make optimum use of the ALS. The major advantage of the ALS to biologists will be the ability to image biological samples in their natural state, unlike the use of electron microscopes which requires chemical or physical alternation of the the samples before their examination. The use of this technology is in its infancy at existing synchrotron light sources, but completion of the ALS will allow for higher resolution imaging for these samples, telling us more than ever before about the biological world around and in us.

These are but two examples of ways in which the coming of the ALS has sparked scientific creativity far beyond the initial research expectations. This creativity needs to be encouraged, and indeed nurtured, by the Department of Energy. This Committee could do the nation a great service by encouraging the Department to support those research initiatives which fully utilize these facilities in support of the DOE mission.

Other BES Programs

Moving on to other parts of the BES budget, I want to put in a particularly supportive word for the Advanced Energy Projects division. This program has the unique, but critically important, responsibility of supporting scientific initiatives that do not quite fit the defined scientific areas of the other BES programs. A good example of this is the Heavy Ion Fusion Accelerator Research Program at LBL. Using LBL's historic accelerator expertise, we are working on an accelerator-based power source to implode deuterium-tritium targets to produce power in a commercial fusion power plant. Studies by the National Academy of Sciences and other panels have given the program good reviews, and have also indicated the feasibility of a commercial plant that might use this technology. Sponsoring this kind of innovative, but potentially risky, research should remain an important part of the Department of Energy's mission, and the Committee should encourage, and adequately support, this important program.

To predict more accurately the location and properties of coal, petroleum and geothermal resources requires a fundamental understanding of complex geophysical and geochemical forces and their action over hundreds of millions of years. The isotopic composition of minerals and rocks can be an accurate tracer of rock-forming processes. The BES Geosciences program is supporting LBL's Center for Isotope Geochemistry to develop advanced high resolution mass spectrometers. These instruments will be used by Laboratory scientists in collaboration with researchers from UC Berkeley and industry. The development and use of these tools will lead to improved techniques for oil and gas exploration and production as well as the location of nuclear waste repositories.

The 1990's offer a tremendous opportunity to undertake major challenges in the computational sciences. The increasing role of computers in our economic and technological developments demands that we continue to "push the envelope" with the development of new computer hardware, software and other advanced computational tools. The Applied Mathematical Sciences division of BES is playing an important role in this effort. LBL, in collaboration with the Princeton Plasma Physics Laboratory (PPPL), has developed the Cooperative Approach to Software Advancement (CASA) initiative. Our work in advancing the use of computational tools in scientific research, through the creation of special-purpose scientific software integrated with commercial software, will strengthen the collaboration between scientists from around the nation. It will permit these collaborations to occur even though the parties may be separated by thousands of miles, greatly increasing our national scientific productivity. Although certainly beneficial to DOE and its mission, this is an area of research whose results will truly be national in scope.

DOE -A Science Agency

Overall, DOE's FY 1990 budget request is very supportive of basic scientific research and especially new initiatives designed to push the research frontier forward. This maintains a trend established in the 80's and supported by the present and past Presidents and especially the Congress. I do not need to remind this Committee that DOE's missions for energy and defense imply a strong commitment to basic research. This commitment makes DOE a science agency on a par with NSF. LBL has benefitted from this support and I believe its contributions, along with those of the other national laboratories, justify your continued and increased support for DOE's basic research programs.

Of particular note is the support given to the SSC from both the Administration and the Congress. LBL has been honored to serve as the home for the Central Design Group for the SSC, in effect its intellectual birthplace. As such, we are somewhat saddened to see it move on to Texas, but are pleased to see such an important scientific idea move toward reality. As the project moves forward, I hope that the Committee will keep firmly in mind the scientific importance of the project and not just focus on the cost of the project.

The Human Genome Project in OHER is another new DOE scientific initiative in which LBL has played a role since its inception. Designated a DOE Human Genome Center by the Secretary of Energy, LBL is moving aggressively forward in developing the new technology necessary to design a cost-effective program to map, and eventually sequence the genetic material that defines man. Progress has already been demonstrated. A related effort in scanning tunneling microscopy, in collaboration with Lawrence Livermore National Laboratory, has provided the first-ever look at the DNA double helix in its "native" state. The applications of this new achievement to the genome project are as yet undetermined, but imaging DNA and its components could become an important part of the genome project. DOE has an important role to play in this project, through support of its centers at LBL and Los Alamos National Laboratory, as well as the work being performed at LLNL. DOE's historic expertise in technology development, as well as the ability to assemble the multidisciplinary teams of researchers needed to advance the project, gives them a unique role in the project. NIH, while more than amply qualified to support single investigator research into the human genome and other model genome systems, does not have the expertise available to DOE in this area. It is a large project that requires the best of both institutions.

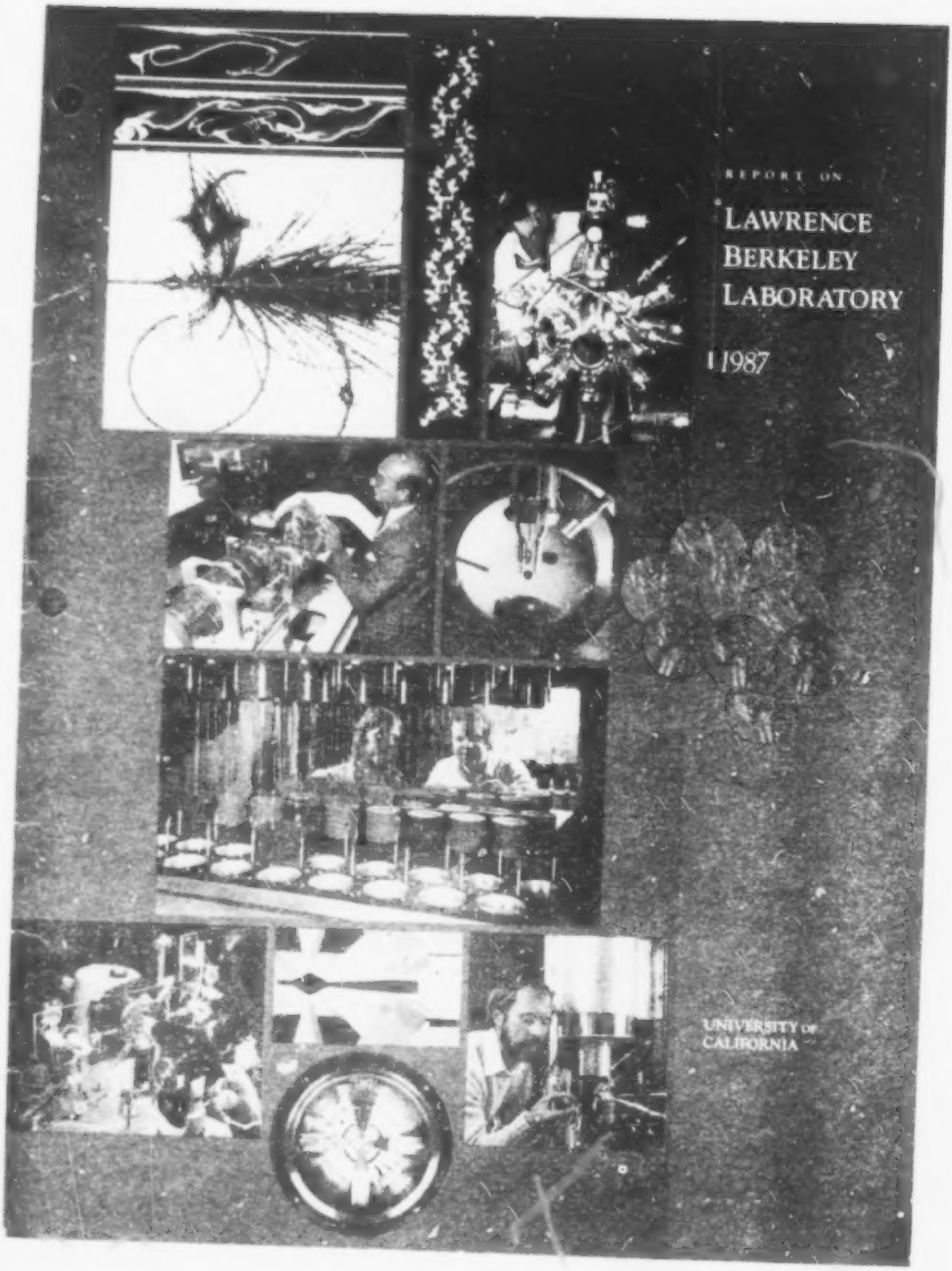
Supporting forefront research into areas such as particle astrophysics - the study of the creation of the universe through the observation of celestial particles - is a natural extension of the fundamental particle physics research pursued in the DOE High Energy Physics program. In this particular field, their support of pioneering work at LBL, and UC Berkeley faculty associated with LBL, resulted in UC Berkeley forming a new Center for Particle Astrophysics. NSF has designated this center as one of their eleven Science and Technology Centers. Stanford, UC Santa Cruz and San Francisco State University faculty and students will also be involved in the Center's efforts. The Center will be directed by a joint LBL-UC Berkeley scientist, and we will play a leading role in the Center research. We are hopeful that DOE can be convinced to support research in conjunction with the Center to strengthen the university-national laboratory connection. Work begun before the Center's creation, supported by DOE, has led to the recent discovery of the birth of a pulsar within Supernova 1987A. In conjunction with Los Alamos National Laboratory, NASA's Ames Research Center and a number of universities and observatories, LBL photon detectors discovered the superdense sphere of neutrons at the Chilean telescope where Supernova 1987 A was discovered. Supernova explosions are believed to be the origin of all chemical elements in the universe, providing the opportunity for researchers to learn more about these chemicals and the beginnings of life itself. The pulsar, with the density of the sun but only a few miles in diameter and rotating on its axis 2,000 times per second, provides a celestial laboratory for studying physical phenomena that do not exist anywhere on Earth.

DOE's support for basic scientific research over the last nine years has made a major impact on the nation's technology-based economy. During that period, LBL has won eight annual awards for the most significant technological advances of that year - the R&D 100 awards. Most of these have come from projects supported by DOE's Office of Energy Research. A prime example is the development, through the support of the Materials Science program, of a new low-cost, high strength steel. A mosaic-like steel composed of two different fibrous phases, FERMAR steel will cost about 25 percent less to produce than steel for reinforced or prestressed concrete. The potential savings could be a third of a billion dollars in the United States, and a billion dollars worldwide. The support of basic research will, in time, produce industrial and economic benefits like our FERMAR steel.

In the area of high-temperature superconductivity, our Center for Advanced Materials and the associated Center for Thin Film Applications are working on the fundamental mechanisms of superconductivity exhibited by these new oxide materials. At the same time, our scientists, in collaboration with industrial partners, are exploring the near-term uses of the new materials in such areas as computational systems and ultra-sensitive magnetic field measuring devices. DOE's support of these efforts, and the transfer of their results to the industrial sector, is important, and needs to be continually encouraged by this Committee. We have followed closely, and with interest, the discussion and development of legislation on technology transfer. If such legislation could provide more authority for the laboratories to develop their own industrial agreements, including patent and licensing agreements, this would greatly benefit the speed with which our scientific research results move into the industrial sector.

In summary, this Committee is to be congratulated for the support it has given DOE in the advancement of the nation's scientific and technological base. It is an important role for DOE, one inherited from the days of the Atomic Energy Commission, and an important one for the nation that goes far beyond the energy-related mission of the DOE. This fact is often forgotten in the debate over future energy supplies, or more recently, the environmental problems associated with the Department's defense mission. DOE is a science agency, a fact that should be better known to your colleagues in the Congress. Supporting growth in the NSF and NIH budgets, which I also support, will not fully maintain the scientific base of our nation. DOE's role in this area, largely through its national laboratories, remain the "hidden jewel" in the crown our nation wears as the world's leading producer of scientific knowledge. Our national laboratories have been revitalized by the renewed support of the Department and the designation of new national user facilities at their site. They are now laboratories in a constant state of evolution, full of creative new scientific ideas in response to our rapidly changing environment. The Department deserves credit for recognizing, and often supporting, these new initiatives. They do, however, need your help to assure that DOE's critical role in basic scientific research is maintained, strengthened and recognized for the excellence of its results.

As Congressman Mineta has so kindly noted, I will be stepping down as Director of LBL at the end of June. It has been an honor and privilege to guide this Laboratory over the past nine years. We at LBL have been proud to contribute our scientific creativity to the nation in support of national scientific and technological goals. With the strong support of this Committee, and the Department of Energy, I am confident that I am leaving the Laboratory in a strong position to continue our contributions to these efforts. I would be pleased to answer any questions.



REPORT ON

LAWRENCE
BERKELEY
LABORATORY

1987

UNIVERSITY OF
CALIFORNIA

REPORT ON

LAWRENCE BERKELEY LABORATORY

1987

UNIVERSITY OF CALIFORNIA

Lawrence Berkeley Laboratory (LBL) is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy (DOE). The Laboratory has more than 3,000 employees, and its budget of $210 million supports a wide range of research activities in fields ranging from astrophysics to energy conservation.

The oldest of the nine national laboratories, LBL is an outgrowth of the Radiation Laboratory originally established on the UC Berkeley campus by Ernest O. Lawrence in 1931. In 1940 Lawrence moved the Laboratory to its present spectacular site on University land in the hills overlooking the Berkeley campus. With the cyclotrons he invented, Lawrence opened new opportunities for research in the formative years of the nuclear age. Today the Laboratory continues to serve the nation through its expanded and diversified research programs.

Its role fulfills a four-part mission: to perform leading multidisciplinary research in energy sciences, general sciences and life sciences; to develop and operate unique national experimental facilities for use by qualified investigators; to educate and train future generations of scientists and engineers; and to foster productive relationships between LBL research programs and industry.

LBL's research activities and accomplishments for 1987 are presented here in the Laboratory's first annual report.

Director's Message

Nineteen eighty-seven was a landmark year—a year that brought to fruition many of the goals that were set early in the 1980s to revitalize Lawrence Berkeley Laboratory. Through redirection, reorganization, and rebuilding, LBL has endeavored during the 1980s to anticipate and discover new ways to meet the changing scientific needs of the nation. We met challenges in new and established programs in basic and applied research. We rearranged priorities and gave new emphasis to the exploration of areas where dramatic scientific advances are promised. We enjoyed increased financial support that reflected the Laboratory's reputation for excellence now and the expectation for continuing excellence in the future. In 1987, the Laboratory that has stood at the forefront of scientific research for more than 50 years was on the move toward the 21st century.

David A. Shirley

Changes in the management structure, described later in this report, along with creation of new biological research divisions, reflect the Laboratory's new emphasis on the life sciences, one of the important changes in direction that are revitalizing the Laboratory and determining its character for the 1990s and beyond.

A highlight of the Laboratory's new initiatives in the life sciences was its designation, in 1987, as one of the Department of Energy's two national centers for deciphering the human genome. The new center will be directed by Charles R. Cantor, an internationally recognized expert in genetic mapping and sequencing who joins LBL and the UC Berkeley faculty from Columbia University. DOE funding for the genome project has increased from $10 million in 1988 to $17 million in 1989, and funding for LBL's human genome work was increased by $400,000.

The first step in the redirection of the Laboratory came in 1982 with a proposal for a major initiative in materials sciences with a next-generation synchrotron radiation source—the Advanced Light Source—as its centerpiece. By the end of 1987, all the originally envisioned facilities were either complete or under construction, and our materials sciences budget had increased from $7 million in 1982 to $44 million in 1988.

Construction of the Advanced Light Source, the most sophisticated accelerator ever built in Berkeley, began in 1987. Almost 50 years earlier, Ernest Lawrence had moved the Radiation Laboratory up the hill to begin construction of the 184-Inch Cyclotron, the machine that pushed back the frontiers of high-energy physics and expanded opportunities for investigation in ~~many~~ fields. It is fitting that the Advanced Light Source will replace the pioneering machine on the same site and under the same landmark dome, where it, too, will define a significant new direction for LBL and for science.

Other construction projects also reflect the Laboratory's shift in direction. The $12 million Surface Science and Catalysis Laboratory, the first major new laboratory building at LBL in more than 20 years, was completed and occupied in 1987. A $28 million Advanced Materials Laboratory will be finished by the end of 1988. This rebuilding is an outward and visible sign of the strength and vitality of the Laboratory as it completes the transition from the leading high-energy physics facility of the 1960s to a dynamic multiprogram laboratory of the 1990s.

But the real vitality of this Laboratory continues to depend upon the creative and innovative individuals who are conducting the research, solving the problems, and developing the ideas. Much of that strength comes from the Laboratory's increasing synergism with the Berkeley campus. Of the Laboratory's 940 scientific staff members, 206 are members of UC faculty, and fully one-quarter of LBL research is now conducted under the leadership of faculty principal investigators. Over the years, eight faculty members have won Nobel prizes while at LBL, the most recent of whom is Yuan T. Lee, who won the prize for chemistry in 1986. But it is all of the Laboratory's men and women, working together, who have enabled LBL to realize its full potential as one of the nation's premier national laboratories.

It is my pleasure to include a few of their many achievements in this report.

David A. Shirley

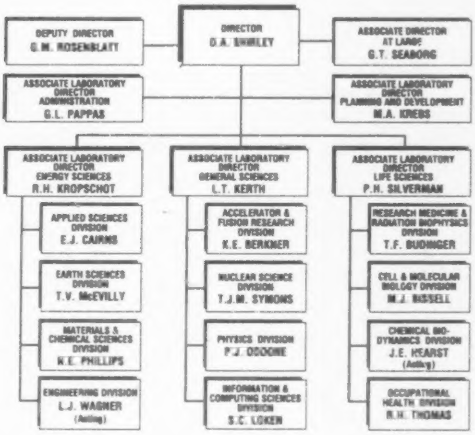
Director

REORGANIZATION

The complexities of science and technology today often demand the involvement of scientists and engineers from many different disciplines and the use of highly specialized, expensive equipment. The cost of such multidisciplinary efforts has never been higher, and the competition for funding never more intense. To compete effectively, LBL has created a new, streamlined organizational structure similar to that of other national laboratories. LBL managers now have the flexibility and increased authority that strengthens their ability to integrate and coordinate scientific programs and promote new initiatives.

Now reporting to the Director are three Associate Laboratory Directors with Laboratory-wide responsibility for specific scientific program areas: Energy Sciences, General Sciences, and Life Sciences. There are also Associate Laboratory Directors for Administration and for Planning and Development. The positions of Deputy Director and Associate Director-at-Large continue, as do the positions of scientific division heads within each program area.

The new organization has been implemented in recognition that, for the foreseeable future, the highly competitive situation in science will continue and only dynamic institutions will thrive.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G.M. ROSENBLATT
ASSOCIATE DIRECTOR AT LARGE
G.T. SEABORG
ASSOCIATE LABORATORY DIRECTOR ADMINISTRATION
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ACCELERATOR & FUSION RESEARCH DIVISION
K.E. BERKNER
NUCLEAR SCIENCE DIVISION
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PHYSICS DIVISION
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OCCUPATIONAL HEALTH DIVISION
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Gerd M. Rosenblatt

Glenn T. Seaborg

Martha A. Krebs

George L. Pappas

INITIATIVES

That LBL is able to compete in these changing times is evidenced by a number of new initiatives that have been funded by the U.S. Department of Energy (DOE). Of these new initiatives, the brightest, literally, is the Advanced Light Source (ALS), an electron synchrotron uniquely equipped with special magnets to produce laser-like beams of soft x-ray and ultraviolet light that will be 10,000 times more brilliant than any light now produced. The ALS will

The Advanced Light Source will be housed under the dome of the historic 184-Inch Cyclotron.

be both an LBL facility for Laboratory scientists and engineers and a "user facility," available to researchers across the nation and around the world. Its beams will enable this new facility to serve many purposes—as a microprobe for studying the atomic structure of materials; a camera that can freeze-frame chemical reactions at twenty-trillionths of a second; a microscope that can safely peer inside living cells; or a tool that can fabricate electronic microstructures with features smaller than a hundred-thousandths of an inch. Light from the ALS also will be able to produce x-ray holograms (three-dimensional images) of structures, including those within a living cell.

Perhaps no other development in technology has generated more public excitement in recent years than the discovery of the so-called "high-temperature superconductors." Superconductivity is a state in which a material loses all electrical resistance. This means, for example, that superconducting power lines could carry a current with no loss in energy, saving the nation billions of dollars in electricity costs.

For nearly 75 years, superconductivity was produced only in metallic materials cooled to nearly absolute zero (-273.15°C), which required the use of expensive, hard-to-handle liquid helium. Then, in 1986, scientists discovered that a certain class of ceramic oxides became superconducting above the boiling point of nitrogen (-196°C). This meant that liquid nitrogen, which is easy to handle and costs less than milk, could be used as a coolant. The race to exploit these discoveries and tap the economic potential of improved superconducting materials is global.

In 1987, to assist and accelerate the efforts of the United States, DOE established four superconductivity research centers. LBL was chosen as the location for the Center for Thin Film Applications. Thin films are materials that are usually only a few hundred layers of molecules thick. Superconductors fashioned into thin films might typically be used in computers, radiation detectors, medical diagnostic devices, and other electronics applications. The LBL Center for Thin Films Applications will serve as a national repository for thin-film information and a focal point for fundamental research on superconductivity and superconducting devices. A major reason behind LBL's selection as the site of this new national center is the strong collaborative research program between its staff and the faculty and students at the University of California's Berkeley campus.

A magnet levitating over a pellet of superconducting material demonstrates high-temperature superconductivity.

LBL also was chosen to host one of two other new centers that DOE established in 1987. Researchers at these centers will participate in the largest single project ever undertaken in the life sciences—the deciphering of the human genome. The human genome is the full complement of genetic material contained in the nucleus of every cell in the human body. This material holds the genetically coded instructions that guide the transformation of a single cell—a fertilized ovum—into a human being.

The ability to read the genome's message could be the most powerful tool ever developed for investigating the mysteries of human development and should be a tremendous asset for the diagnosis and prevention of cancer, heart disease, sickle cell anemia, and more than 3,000 other afflictions that have been linked to a breakdown in the genetic process. Deciphering of the genome should also prove enormously valuable in the diagnosis and treatment of genetic damage caused by such environmental pollutants as radiation and toxic chemicals—a prime concern of DOE.

LBL's Human Genome Center will contribute to mapping and sequencing the genome, which involves pinpointing the location of genes on chromosomes, then determining the order in which the nucleotides are arranged along each of these genes. Although everybody's genome is unique, the variation from person to person is only about a tenth of one percent, so a model of one genome can serve as a standard reference. Constructing such a model will require mapping up to 300,000 genes and sequencing approximately 6 billion nucleotides. Utilizing its special capabilities as a national laboratory, LBL will bring together life scientists, computer scientists, and instrumentation engineers to develop new technologies that will permit speedier, cost-effective mapping and sequencing. New database management techniques to support quick and accurate decoding of the genetic message also will be developed. Scientific responsibilities will be shared with

High school science students from across the nation converge on LBL for a special summer training program.

researchers on the Berkeley campus. LBL has proposed an "upgrade" that would greatly extend the scientific usefulness of an existing accelerator, the Bevalac, at far less than the cost of building a completely new facility with comparable capabilities. The Bevalac consists of three machines operating in tandem—the Bevatron (a proton synchrotron), a local injector, and the SuperHILAC (Heavy Ion Linear Accelerator). Capable of boosting the energies of any ion to around 2 billion electron volts, the Bevalac has a proud past. However, its main component, the Bevatron, is 34 years old and needs to be modernized. The proposed upgrade would increase the intensity of the Bevalac's beam as much as a thousandfold and provide pulses of uniform intensity. Other beam properties also would be significantly improved, and the percentage of operating time during which the machine is actually accelerating ions, now about 25 percent, would be increased to 95 percent or more. The upgrade also would permit fast switching between different kinds of beams so that the Bevalac would be able to accommodate medical and nuclear science programs simultaneously. The Bevalac would continue to operate as a national user facility.

FACILITIES

With other proposals under consideration as well, LBL's prospects for the future look good. Maintaining this competitive strength, however, will require the replacement of outdated facilities. As of 1987, the average age of LBL's main buildings was 30 years. Much of the mechanical and electrical utilities equipment is outdated. Supported by the Board of Regents, LBL has developed a 15-year plan under which, by the year 2000, buildings, utilities systems, and roads will be either rehabilitated or replaced.

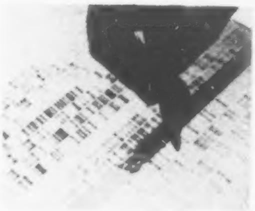
TRAINING & EDUCATION

Although research is the primary activity at LBL, the Laboratory is also charged by DOE with providing training for the next generation of scientists and engineers. More than 600 graduate students conduct thesis research at LBL, and educational enrichment programs for precollege and college students, and for science teachers, are offered as well. The number of these programs has expanded considerably within the past year. To coordinate its increasing educational efforts, LBL has established a Center for Science and Engineering Education. This center manages programs for high school science teachers and high school students, as well as minority outreach programs that encourage black and Hispanic science students.

TECHNOLOGY TRANSFER

In addition to working more closely with educational organizations, LBL is also forging stronger ties with U.S. industry. In 1987, the Laboratory put increased emphasis on disseminating information about LBL research to industrial scientists and expanding the utilization of this research through patents and licensing activities. Five LBL inventions were among the 100 "most significant new technical products" selected by *Research & Development* magazine for its 1987 IR-100 awards, presented for "outstanding achievements in technology."

The Laboratory also looks to establish more collaborations with U.S. industry along the lines of those now in progress at LBL's Center for Advanced Materials (CAM) and the Center for Building Sciences (CBS). At CAM, LBL researchers attack problems that are blocking industrial development of exotic new materials, such as stronger-than-steel plastics and faster-than-silicon semiconductors. At CBS, the investigation of efficient new building components, computer models, and data and information systems could translate into enormous savings in the nation's energy costs. Both centers also provide training for industrial researchers.



The sequencing of some 6 billion nucleotides will be required to construct a model of the human genome.

Energy Sciences

Richard H. Kropschot
Associate Laboratory Director
for Energy Sciences

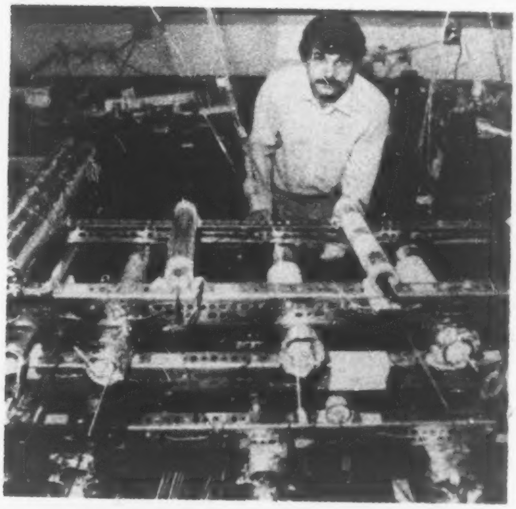
Energy Sciences research at LBL encompasses a broad spectrum of energy science and technology that includes programs in materials science, chemistry, physics, geology, and engineering. New energy sources, the tradeoffs between efficient energy use and increased energy supplies, and the disposal of energy wastes are explored. The impact of energy technology on health and the environment also is investigated. This research is carried out by four divisions—Materials and Chemical Sciences, Applied Science, Earth Sciences, and Engineering.

National energy policies as implemented by DOE dictate where emphasis is placed. For example, if the spectacular potential of high-temperature superconductors is to be realized, the mechanisms behind this phenomenon must be understood. To help achieve this understanding, scientists in the Materials and Chemical Sciences Division and LBL's Physics Division are studying the "isotope effect"—the change in the critical temperature for superconductivity resulting from a change in the atomic mass of one of the superconductor's constituent elements. First observed in the 1950s, the isotope effect provided the clue that led to the establishment of the generally accepted Bardeen-Cooper-Schrieffer theory of superconductivity.

Recent experiments at LBL have shown isotope effects that are not consistent with the BCS theory in the highest critical temperature superconductors. This suggests that more than one mechanism may be at work in these materials.

Geochemical analyses of the isotopes of elements in the earth's crust can tell much about the earth's geological history. Such analyses can also help predict the location of deposits of petroleum, coal, and natural gas. The capabilities for doing the best possible analyses will be provided at the Center for Isotope Geochemistry, which has been established in LBL's Earth Sciences Division in collaboration with UC Berkeley. Building on LBL's existing expertise in multi-isotope sampling and analysis, researchers at this center will study and develop models of geological and geochemical processes. They also will refine and develop techniques and instrumentation for mass spectrometry and microsample analysis.

During the past two decades, much attention has been paid to the effects of combustion products on outdoor air quality. In LBL's Applied Science Division, scientists have been studying the effects of combustion emissions and other pollutants on indoor air quality as well. The concern has been that ambitious programs to reduce energy consumption by reducing ventilation might be aggravating indoor air pollution. LBL researchers are finding, however, that the rate at which the pollutant enters a house or building, not ventilation, is the most important factor in determining the indoor concentrations of any pollutant.



An array of ovens allows precise control of temperature and baking time in the production of materials for experiments in high-temperature superconductivity

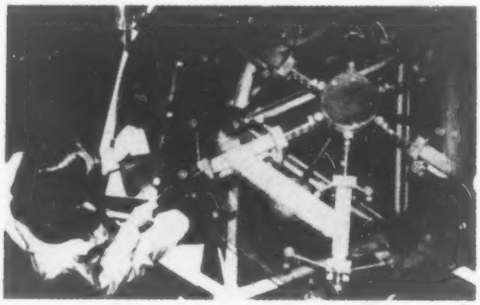
Measurements made in homes around the nation helped determine the source and degree of indoor radon pollution.

A case in point is radon, a radioactive gas that arises from the decay of naturally occurring radium, which is a trace constituent of soils, rocks, and construction materials. According to an LBL study, occupants of a million homes, from Maine to Oregon, appear to be receiving radiation doses greater than those received by the average uranium miner. The risk of lung cancer (from alpha particles emitted by radon decay products) to families in these homes is far more significant than health risks typically caused by toxic wastes, power plant and auto emissions, or many other atmospheric pollutants. Measurements made in more than 1,400 homes, located in 38 areas across the nation, showed very little correlation between ventilation and radon levels. From these data, researchers have concluded that what is crucial is the source of the radon, and that, in nearly all cases, that source is the soil. Radon is sucked out of the ground and drawn into houses through cracks, pores, and other openings by pressure-driven air flows. The pressures that create and drive these air flows are generated by indoor-outdoor temperature differences and wind.

Not all of the focus in the Energy Sciences programs is earthbound. Researchers in the Engineering Division are participating in a joint effort involving more than 100 scientists and engineers from LBL, the University of California, and the California Institute of Technology to develop what will be the world's largest optical telescope. Featuring a primary mirror 10 meters wide, the Keck telescope will enable scientists to see galaxies more than 10 billion light years away—double the range of any existing telescope. A $70 million grant from the W.M. Keck Foundation (to honor the late businessman William Keck) is financing construction of the observatory at the summit of Hawaii's Mauna Kea.

Expected to first operate in 1990, the Keck telescope's most unusual feature will be its segmented primary mirror—the invention of LBL physicists. Instead of a single gigantic (440-inch diameter) reflective mirror, the Keck primary mirror will be a mosaic of 36 hexagonal segments, arranged in the form of a honeycomb and kept in precise alignment by a computer-controlled system so that they function as one entity.

LBL engineers have completed the design and are now assembling spidery-looking structures, called "whiffletrees," which are part of the primary mirror's "passive" support system. Each mirror segment will weigh about 1,000 pounds and be supported underneath by three whiffletrees. Design work has also been completed for the "active" support system, consisting of electronic sensors mounted on segment edges, and motor-driven adjusting mechanisms (actuators) connected to the back of each segment. One hundred times a second, the sensors will compare heights with their neighbors (variations of 40 billionths of an inch can be detected). This information will be relayed to computers that will then direct the actuators to make necessary adjustments twice a second.



An elaborate computer-controlled system of electronic sensors and motor-driven actuators will keep mirror segments for the Keck Telescope in precise alignment.

General Sciences

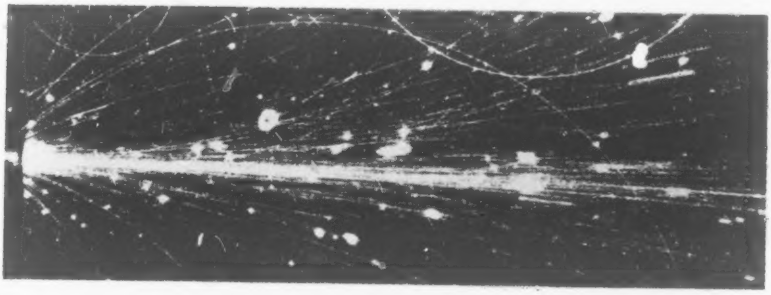
Leroy T. Kerth
Associate Laboratory Director for General Sciences

General Sciences programs also are carried out by four divisions: Physics, Nuclear Science, Accelerator and Fusion Research, and Information and Computer Sciences.

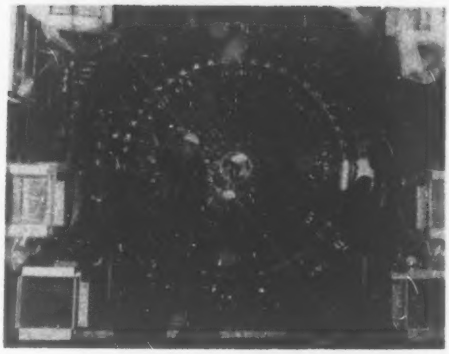
The Physics Division performs theoretical and experimental research in high-energy particle physics, astrophysics, and applied mathematics. A major part of the effort in high-energy physics is the design, construction, and operation of particle detectors—the instruments that capture and record the results of high-energy collisions taking place in accelerators. Physics Division scientists played significant roles in the development of two of the world's largest detectors, the Collider Detector facility and the D-Zero facility, which were designed for use at the Fermi National Laboratory's Tevatron, the world's highest energy accelerator. Two other large, LBL-designed detector systems—the Time Projection Chamber and the Mark II—are currently located at the Stanford Linear Accelerator Center. These systems provided data that cast doubt on a proposed explanation of why the number of solar neutrinos detected is only a third of what physics models predict. According to this proposal, a type of WIMP (weakly interactive massive particle) cools the core of the sun by conducting energy to the surface. (A cooler core would mean fewer solar neutrinos.) Experimental results from the Positron-Electron Project, an accelerator that operates with the TPC and Mark II to create and analyze collisions between electrons and their antimatter counterparts, showed no particles with properties that fit the proposed WIMP.

In the Nuclear Science Division, the emphasis is on the study of the nuclei of heavy ions during reactions that take place at low, medium, and high energies. From such basic knowledge can come the means to create exotic new isotopes, or possibly even new elements, with valuable chemical properties. Nuclear physics experiments are conducted at LBL on the 88-Inch Cyclotron, the SuperHILAC, and the Bevalac. Additional experiments are being conducted at other facilities, such as the giant proton accelerator at CERN in Geneva, Switzerland.

Much excitement has been generated within the physics community over the latest experimental results of a collaborative team of LBL, Stanford University, and Lawrence Livermore National Laboratory researchers. Using LBL's SuperHILAC, the team found evidence of the existence of a new neutral particle, different from any detected before. If real, this new particle would not fit into any of the established families of elementary particles. It would be a very light particle—only a few times heavier than an electron—and would be electrically neutral. Evidence of the new particle was revealed when a beam of uranium ions was collided with a target of thorium. The collaborating team is cautious about making claims until a follow-up experiment has been completed.



High-energy nuclear collisions, like this one from LBL experiments at CERN, produce showers of particles for analysis by physicists.



The Mark II particle detector, now at the Stanford Linear Accelerator Center, is one of many LBL-designed detector systems in use at accelerators here and abroad.

Responsibility for the operation and maintenance of the SuperHILAC and LBL's other accelerators, including the Advanced Light Source, now under construction, belongs to the Accelerator and Fusion Research Division (AFRD). Scientists and engineers in this division also design new accelerators and test new concepts in accelerator technology. This technology could be a critical factor in determining whether nuclear fusion, a virtually inexhaustible source of energy, will ever become commercially viable. One of the most promising of the new concepts in accelerator technology that AFRD scientists are exploring is the Two-Beam Accelerator (TBA). The TBA is a proposed high-energy electron linear accelerator that would solve a problem facing particle physicists. Exploring the fundamental aspects of the physical world means taking particles to ever higher energies, which, in the past, has meant larger and larger machines.

Finding the space to locate these giants has become so difficult that the proposed Superconducting Super Collider, with a circumference of more than 50 miles, is probably the last of its breed. The TBA uses one beam of electrons to generate high-power microwaves that, in turn, are used to accelerate the electrons in a parallel beam to ultrahigh energies at 10 times or more the best rate of today's machines. This drastically reduces both accelerator length and power requirements, making for a far more compact high-energy machine.

Originally, the TBA's microwaves were generated by a free-electron laser, a device that uses a special magnet, called an "undulator," to amplify the energy in a beam of electromagnetic radiation. In recent tests at the Lawrence Livermore National Laboratory, a TBA was successfully powered by a relativistic klystron, a device that produces microwaves from a beam of electrons traveling at nearly the speed of light.

AFRD is also responsible for the Center for X-ray Optics, the only scientific research center devoted exclusively to the study and utilization of low-energy x-rays and ultraviolet radiation. The center provides the new technology needed to utilize effectively the new generation of light sources exemplified by the ALS.

The Information and Computing Sciences Division (ICSD) maintains LBL's computer facilities, its library, and its publishing facilities, which include both printing and graphic arts capabilities. In addition to providing these support services for the rest of the Laboratory, ICSD directs basic research programs in computer science. The thrust of these programs is on the development of database management and distributed computing systems designed to handle the increasing complexity of scientific data and make scientific computing more effective. ICSD researchers also look for new scientific applications of current computer technology. A recent success was the development of a low-cost technique for animating graphic displays on video tape. Setting graphic displays into motion can provide an entirely new perspective on scientific data, especially for time-dependent processes, such as turbulence or diffusion, or the changing shape of a particle accelerator beam. Video movies can also be used to provide unique three-dimensional views of structures or simultaneous views from different angles of complex surfaces. Video movies can be shared between scientists at different locations via electronic mail.

Researchers have developed a technique for animating graphic displays on video tape to provide a new perspective on scientific data. This image of the heart can be rotated on the screen so that blood flow is visible.

ten | Life Sciences

Paul H. Silverman
Associate Laboratory Director for Life Sciences

LBL is widely known as the "birthplace" of nuclear medicine because it was former Regent John Lawrence, brother of LBL founder Ernest O. Lawrence, who, in 1936, became the first physician to use a radioactive isotope in the treatment of a human disease. Fifty years later, this pioneering effort has been greatly expanded in response to wide-ranging national needs, and the Life Sciences programs at LBL are being given a greater emphasis and priority than ever before.

Medical research on the use of radiation to treat human afflictions continues to be a prominent feature of LBL's Life Sciences programs. Beams of high-energy charged particles, produced in the Bevalac, are being used to kill cancerous tumors and cauterize a deadly type of blood clot called an arteriovenous malformation in critical situations where conventional surgical procedures cannot be used. As a result of the success of these treatments, at least 12 accelerators dedicated to biomedical purposes are either planned or being built at various locations around the world.

LBL has also gained international recognition for developing safety standards in the use of accelerators for medical treatments. The staff of the Occupational Health Division provided the definitive measurements of the radiation environment in the Tevatron, and, in collaboration with CERN, published a report entitled: "The Radiological Safety Aspects of the Operation of High-Energy Proton Accelerators." This report is being used in the planning of the proposed Superconducting Super Collider.

John Lawrence and his associates found that the different tissues in the body displayed selective preferences for certain radioactive isotopes and they used this preference for disease diagnosis. From those early efforts evolved the sophisticated radioactive tracers being developed at LBL today. The radiotracer program features the use of isotopes that disappear from the human body within seconds. This means that much larger doses can be administered to a patient and that tests can be repeated or modified during a single treatment session.

LBL is also a world leader in biomedical imaging. Through the detection and counting of signals from radioactive decay, nuclear spin, or other physical phenomena induced within an organ or tissue, the imaging techniques developed at LBL can provide three-dimensional views inside the body without having to dissect it. Researchers in the Research Medicine and Radiation Biophysics Division are using these imaging techniques to study diseases of the brain and heart. Recently, a combination of three techniques—positron emission tomography, single photon emission computer tomography, and nuclear mag-

A new positron emission tomograph system, able to image the human head with a spatial resolution twice as fine as any other in the world, is among the array of biological imaging equipment at LBL.

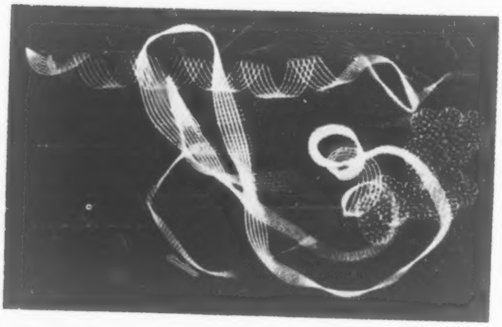
Scientists at LBL have developed unique retroviral vector-packaging cells that express the cancer-causing mutations of genes

netic resonance—yielded new information about Alzheimer's disease, the mysterious decline of mental faculties that afflicts one out of every four elderly Americans. By studying glucose metabolism and the patterns of blood flow to the brain during progressive stages of Alzheimer's disease, the LBL researchers discovered that the hippocampus is particularly sensitive to the presence of the disease and becomes atrophied early at the outset. The hippocampus is in the so-called "grey matter" of the brain and plays an essential role in memory and learning.

Researchers in the Chemical Biodynamics Division, collaborating with Berkeley campus faculty and Japanese scientists, scored a major breakthrough in cancer research when they determined the first three-dimensional structure of an oncogene protein. This knowledge should be valuable in the design of drugs that can stop the protein's cancerous activities. Oncogenes are cancer-causing mutations of the genes that regulate the growth and development of cells. One of the most common is the "ras" (from rat sarcoma) oncogene, which is found in about 40 percent of human colon cancers, as well as in breast, lung, and bladder cancers. The *ras* gene codes for the construction of a protein that signals for cell division to start or stop. If a genetic mutation results in a defective code, the altered protein may not be able to stop the cell division it starts, which can lead to the formation of deadly tumors. Knowing the protein's three-dimensional structure will help researchers locate where alterations occur and relate these alterations to how the protein functions. Drugs can then be designed to either block the activity of the altered *ras* protein, or restore its functioning to normal.

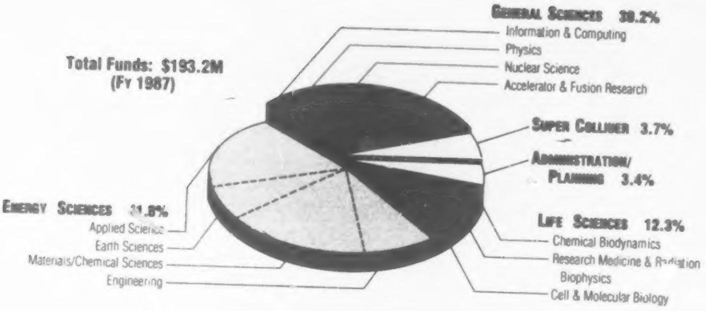
In the Cell and Molecular Biology Division, scientists have developed what are called "retroviral vector-packaging cell lines." These unique cells will express oncogenes without spreading the disease. They can be used, among other purposes, to investigate the conditions under which an oncogene becomes activated, study how biological systems develop, or trace the lineage of cells for studies of genetic heredity. The cell lines, which can be packaged with any kind of foreign gene, can also be used to make transgenic models—organisms whose cells contain foreign genes that were artificially introduced, then passed on to subsequent generations.

This is the first retroviral vector-packaging system to use avian (bird) cells. Similar packaging systems have been developed for mouse cells and are used to make transgenic mice for studies of such genetic diseases as sickle cell anemia. While transgenic mice are good for studying biological developments that take place after birth, transgenic avian models are better suited for studying prenatal events and abnormalities. The reason for this is that an egg and its embryo are easily observed and manipulated during prenatal development, whereas once an altered mouse embryo has been returned to the womb, it is out of sight and reach.



Determination of this three-dimensional structure of an oncogene protein could be a milestone in the fight against cancer

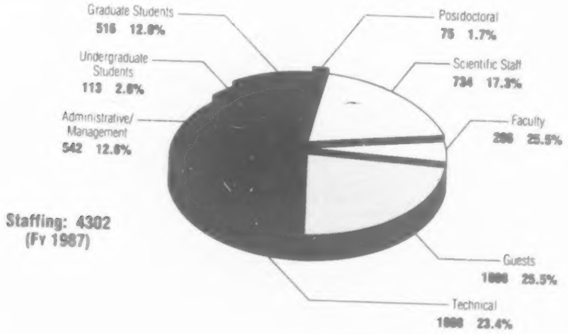
Funding



	FY 1987 (actual) $M	%	FY 1988 (estimated) $M	%
ENERGY SCIENCES	**80.4**	**41.6%**	**80.4**	**38.2%**
Applied Science	20.6	10.7%	21.5	10.2%
Earth Sciences	10.7	5.5%	11.3	5.4%
Materials & Chemical Sciences	34.3	17.7%	34.5	16.4%
Engineering	14.8	7.7%	13.1	6.2%
GENERAL SCIENCES	**75.2**	**39.2%**	**88.1**	**42.0%**
Accelerator & Fusion Research	43.9	22.7%	55.7	26.5%
Nuclear Science	14.5	7.5%	14.4	6.9%
Physics	13.6	7.1%	14.7	7.0%
Information & Computing Sciences	3.2	1.7%	3.3	1.6%
LIFE SCIENCES	**23.9**	**12.3%**	**24.1**	**11.5%**
Cell & Molecular Biology	9.9	5.1%	9.9	4.7%
Research Medicine & Radiation Biophysics	10.2	5.3%	10.1	4.8%
Chemical Biodynamics	3.8	1.9%	4.1	1.9%
Occupational Health*				
ADMINISTRATION/PLANNING AND DEVELOPMENT	**6.6**	**3.4%**	**7.3**	**3.5%**
Superconducting Super Collider	7.1	3.7%	10.0	4.8%
LABORATORY TOTAL	**193.2**	**100.0%**	**209.9**	**100.0%**

* The Occupational Health Division receives no program funding; it operates on overhead

Staffing



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PANEL 3 DISCUSSION

Mr. **Boucher**. Thank you very much, Dr. Shirley.

One question that I think is on the minds of many members of this committee is the effect that funding for the Superconducting Supercollider will have on other programs within the purview of Basic Energy Sciences and General Sciences.

The funding for the SSC is estimated at something like $5.3 billion over a 7-year period. The administration is asking for $250 million for fiscal year 1990, of which $160 million will be for construction.

I would appreciate members of this panel giving some response as to what you think the effect is going to be, whether you have the concern that we have, and generally whether in view of that concern you would advocate funding for the SSC.

Dr. Samios, let's begin with you.

Dr. **Samios**. It has been gone over two times already. I don't know if I have anything deep to add to it. Let me make a physics statement first, since that is my province.

The SSC is designed to explore the one Tev mass range. It is my belief if the SSC isn't built, some machine will have to be built that explores that mass range or particle physics will come to a standstill.

Physics is an empirical science. There are many, many theories that try to extrapolate from where we are now, which is the 100 GeV mass range higher. We have strong beliefs that the theory we have to date doesn't extrapolate well. To put it succinctly, there are 17 numbers in the theory, none of which can we calculate. That shows you our difficulty.

Therefore, it has to be done. The question is who?

The budgetary issue is a very complex one. I strongly support the SSC. I think it has to be done. I would like to see America do it. The technology is in hand. We know how to do it. It's a matter of committing to do it.

Should it affect the other programs, the first order? We all say no. In our hearts, we know the second order, it will. And in a certain silent way, we are accepting that second order. We hope it is not us or some other way.

Given the best of all possible worlds, we say what other people in our position would say, you know, it's a trillion-dollar national budget, you know, it's a small thing.

I agree with the comments that were made by the previous panel. High-energy physics I think has been responsible. It had set its priorities. It has shut down accelerators. It had been at a higher budgetary level when we have had large construction projects.

What is being requested is another bump in the budget which will go down. It certainly will go down because, as you well know, physicists vote with their feet ultimately, and when a project becomes dull, you don't have to close it down, people walk away from it.

So, I think it's a willingness of the society.

I should like to take a shot while I have it. I am sorry Mr. Barton isn't here. I think RHIC construction is in the uncertainty of the SSC construction, certainly less than the contingency.

Mr. **Boucher**. Well, while we're talking with you, let's pursue that subject somewhat. What, in your view, are the consequences of further delays in RHIC construction?

Dr. **Samios**. "When did I stop hitting my wife." We have been delayed for several years now. We were ready in '88. We waited '88, '89, and now people are saying delay will be 1990.

Let me take the positive aspect. We were pioneers in this physics of relativistic heavy ions. We thought this would be a new field. We've done the preparatory exploratory research that is demonstrating that it's an exciting new field, and we have a community that is building up very rapidly that is accepting that.

The conjectures we had whether we will see a new state of matter, now we can state with a high confidence that we will do it, and we have a design that does it.

The physics is there, and as I mentioned in my testimony, technically we are ready.

What is the down side? The down side is we are losing an opportunity of getting people and money external to the U.S. budget. Physicists are very clever people. They don't get active on a thing until they know it's a reality. Plans are being made all over the world to what other opportunities there are. In particular, the Europeans are looking at other options in this field which are of a lesser note than RHIC. However, if they bear fruition, they will go that, even if it's lesser, because it's real.

At a certain point they have to make that decision—and that is occurring in the next year—whether they will devote their money, the resources, and people to that lesser thing instead of RHIC. The amounts we are talking about are not minuscule. They are $10 million, $20 million, $30 million, $40 million. OK. Both European and Japanese.

So, the timing is important to get the hearts and money, the funding that would help the project.

In particular, at Brookhaven we have had a cadre of experts in superconductivity around for a long time. It is certainly demoralizing doing R&D, R&D, and not getting on with the project. Okay. We have a delicate problem that we are active on SSC and we want to get on with RHIC, and we have a delicate baton exchange where we will reduce our activities on SSC R&D and picking up on RHIC. And I as a director have a responsibility to make certain we do that without losing this expertise.

Finally, unless a project has the blessing as a construction project, it's difficult to recruit some of the extra people we will have to do.

So, it's money, people, recruitment, morale problem, and the loss of a great opportunity for the United States at a relatively low cost in this time of budgetary constraints, to do this great project. As I said, to do it anywhere else it would cost twice as much.

Mr. **Boucher**. This committee has not had a very good explanation from the administration as to why no funding was recommended for RHIC. Do you personally think that considerations with regard to the SSC have led the administration not to recommend funding?

Dr. **Samios**. I don't believe so. It is my understanding that the DOE did go forward with funding this year, and it was stopped in the OMB level. So, we have had strong support, as you heard Dr. Hunter earlier, strong support from all levels of DOE and the community.

So, as far as the administration was concerned, and DOE, there is strong support. It was a budgetary issue, I believe.

Mr. BOUCHER. So, from the science end of it there was support, it was simply a budgetary consideration that prevented the administration from recommending the funding?

Dr. SAMIOS. That is my understanding.

Mr. BOUCHER. Let me ask you one other question on that. How much funding do you recommend for 1990 for RHIC?

Dr. SAMIOS. We would go along with the DOE request, which is $15 million.

Mr. BOUCHER. All right.

Gentlemen, we got diverted from your responses. I would appreciate, Dr. Morse, Dr. Garvey, and Dr. Shirley, your response to the earlier question which dealt with consideration of SSC funding and the effect that will have on the budget for your programs and, in light of those possible concerns, whether you would advocate funding for the SSC.

Dr. Morse?

Dr. MORSE. I will defer to Dr. Garvey the comments about the SSC.

I would like to add a little bit about what Dr. Samios has just said. In particular, with respect to the vitality of the field in nuclear physics as opposed to the high-energy nuclear physics, there are sort of three legs in the experimental world that that stands on: the electron beam machines, the heavy ion colliders, and the hadron machines.

We are now into the next generation with CEBAF on the electron machines. It is high time for the next generation of the heavy ion collision-type machines, the RHICs. LAMPF is a facility that is a generation old. And the longer RHIC is delayed, the longer CEBAF takes to get built, the greater the delay in the third leg of that community.

So, for the health of the entire community, I believe it's important for RHIC to get funded and for hadron facilities to take their next step.

Dr. GARVEY. Yes, we're in the position at LAMPF of really being somewhat further down the priority chain.

In answer to a query of Mr. Schiff's about the setting of scientific priorities, they are within individual disciplines set pretty tightly. So the orderly sequence of building CEBAF, getting on to a relativistic heavy ion collider, and then upgrading our capability in light hadron physics is clearly the way the community sees its priorities.

Of course, with RHIC not being in the budget and the SSC having clearly a large but indeterminate budget impact, the future is murky. And I think Leon chose the right word in saying that he appears somewhat terrified by it. I am, too, because we are looking now at very long stretchouts before real construction of absolutely first-rate scientific facilities will take place. And I think the realities are that the whole scientific machinery in this country and possibly worldwide is being slowed down a great deal by these actions.

To remedy this and to put us on a scientifically optimal course, I think Leon's estimate of probably doubling the budget in basic research is about the right order of magnitude to keep all of basic research in this country moving on a nearly optimal trajectory judged by its own internal evaluation.

Dr. **Morse**. To answer the specific question, we do support the SSC. It is an important, exciting part of physics.

Mr. **Boucher**. Thank you.

Dr. Shirley?

Dr. **Shirley**. I think it's very important to move ahead rapidly with the construction of the SSC. I think that it should be supported by all branches of science because it represents not just high-energy physics but it represents and, I believe, supports and inspires scientists in all disciplines. It inspires young people to be excited about science.

One of our greatest shortages in this country, in my opinion, in terms of scientific resources in the coming decades is not going to be funding, it's going to be the number of talented young people entering the sciences. And I believe that that will be greatly stimulated if we go ahead with the SSC.

We might also contemplate the consequences of not going ahead with the SSC. I think as we approach the millennium, the image that this country would project by walking right up to this project and then walking away from it would be very negative, and I think that historians might well identify that as the turning point when America had decided not to try to compete seriously in high-technology activities in the coming century.

Mr. **Boucher**. Well, thank you all for that response. What I assume that you are also saying is that you do have some concern about the potential for the SSC to adversely affect funding for this variety of other projects, which I know are near and dear to all of you.

I would further assume that you would say to this panel that you would want your projects to go forward and funding along with the SSC and that we should not allow that to get ahead in terms of priority of the projects that each of your labs would be advocating.

Anybody disagree with that statement? That is what is known in court as a "friendly leading question."

[No response.]

Mr. **Boucher**. OK. Thank you very much.

Mr. Morrison?

Mr. **Morrison**. Thank you, Mr. Chairman.

I have a growing interest in user-type facilities, and I wanted to ask probably Dr. Garvey about the LAMPF facility.

Of course, you're providing a wide range of services to a variety of customers. I wanted to know do you charge a fee for being used to help pay for improvements in the facility?

Dr. **Garvey**. No. The beam is provided to all users free of charge.

Mr. **Morrison**. Has there been consideration of a fee schedule to help you meet some of the budget pressures?

Dr. **Garvey**. We have not talked about that or thought about it. It seems to work much more effectively in the operation of these facilities that, for example, the nuclear physics program of the Department of Energy provides the operating support for the facility.

And for example, nuclear physics often uses the facilities of high-energy physics or some of my colleagues in fact have had to go and use synchrotron light sources to do work that was basically driven by nuclear physics.

So, there seems to be in place a rather sensible plan of where one part of the department takes sole responsibility for operating one of these large facilities, and it is then open to all users on the basis of scientific merit.

Mr. **MORRISON**. OK. Do you have a cost figure on upgrades?

Dr. **GARVEY**. We for example, this large Cerenkov detector costs about $28 million in capital equipment and would require additional engineering support of about $12 million spread out over the next three or four years.

Mr. **MORRISON**. OK. Thank you.

Those are the only questions I have, Mr. Chairman.

Mr. **BOUCHER**. Mr. Schiff?

Mr. **SCHIFF**. Thank you, Mr. Chairman. I have no questions. I just want to thank the panel for their testimony.

Mr. **BOUCHER**. The Chair also thanks the panel.

Your prepared statements are made a part of our record, and we will review those as well as your oral presentations in making decisions concerning the budget for FY 1990.

Thank you for being with us.

Mr. **MORRISON**. Mr. Chairman, we also give our very best to Dr. Shirley as he moves on.

Dr. **SHIRLEY**. Thank you very much.

Mr. **MORRISON**. Good luck to you, sir, and we trust you will be back.

Dr. **SHIRLEY**. Thank you.

Mr. **BOUCHER**. The fourth panel this morning is composed of two witnesses: Dr. Jon Veigel, the president of Oak Ridge Associated Universities; and Dr. Lee Peddicord, the assistant director for research at the Texas Engineering Experimental Station at Texas A&M University.

Gentlemen, we welcome you to the subcommittee this morning. We will be happy to receive your statements. Without objection, your prepared statements will be made a part of the record, and we would appreciate your summarizing your testimony for us.

Dr. Veigel, we will begin with you.

PANEL 4

STATEMENT OF DR. JON M. VEIGEL, PRESIDENT, OAK RIDGE ASSOCIATED UNIVERSITIES

Dr. **VEIGEL**. Yes, sir. Thank you, Mr. Chairman. I certainly will do that.

Oak Ridge Associated Universities has been a management operating contractor, like the multiprogram laboratories since shortly after World War II. I am not here today to talk, however, about our activities as a national laboratory but rather to address myself to an initiative originally proposed by the chairwoman of this committee, Congresswoman Lloyd, for a summer camp for high school science students.

I would like to do so by considering three questions:

Why should we care; what has already been done; and what is the young American scientist summer program all about in the first place?

In answer to the question why should we care, our professional work force is a critical and usually invisible component of our national security infrastructure, whether that security is considered from its military or its economic perspective. We expect to experience in this country a projected shortfall of 400,000 bachelor degree scientists and engineers and 8,000 Ph.D's by early in the next century.

Solutions take time. In essence, the time scale to produce a scientist is equivalent to the time scale we have been talking about here this morning to produce the SSC, when you consider that we need to influence these students no later than certainly than their high school years to make these choices.

High school is one critical place to impact that career decision, and particularly when there are hands-on activities that they can participate in, from which they can get a sense of what research is about.

As a rule of thumb for you, of 500 high school sophomores in class as we speak today, one of those will have his or her Ph.D. by the turn of the century and not until then. It is exacerbated by the high school student population dropping until the early 1990's and made more critical in that the interest on the part of some groups of those students in science is dropping precipitously; white males, for example, who have provided the historical source of most of our scientists and engineers.

The interest of minorities and females in science and engineering seems to be holding stable, but unfortunately it is not increasing.

Interestingly enough, just to stay at the 1984 production levels of degrees, given these competing factors that I have talked about, we would need to raise the number of students as a percent of the total student body majoring in science and engineering by 50 percent in the next few years.

My personal belief is that the country may be at the leading edge of a focused national spotlight on science education, like the post-Sputnik programs of the late 1950s, now obviously driven by other issues, primarily the competitiveness and productivity issues.

Now I would like to talk briefly about what already is being done in hands-on research programs for students. NASA for a number of years in students in the range from 4th to 12th grade has been offering 1-week space camp programs to a total of about 15,000 students a year. The Department of Energy has for over 2,000 minority students been offering a prefreshman engineering program for about 300 students, a high school science student honors program, and a minority challenge program that in its initial phase, with ORAU in the management role for it, is working with 30 students in which member universities of my organization have committed to provide scholarships through college and in some cases through graduate school for students who are just in junior college at the moment.

The National Science Foundation has a young scholars program, 2,500 students annually now, expanding to 4,700. NIH has a minority program for about 1,000 students. The Army has a program for about 1,000 students.

On university campuses, of 90,000 total students served in a year, only about 2,000 of them offer hands-on experience at less a $300 charge for the student to come there and partake of that program.

Now, given all that, what is the young American scientist summer camp program? It is a 1- to 2-week program to be offered at 20 to 25 university campuses around the country that would on an annual basis serve about 1,000 students at about $1,000 per student, where the student is given no stipend and no travel money, but this rather covers his or her room and board, all the faculty time, et cetera.

The goal, as I see it, is to give them the taste and the flavor of the satisfaction of science by contacts with practicing professionals from academia, industry, and Government, to give them the personal experience of dealing with the challenge of research themselves, and to expose them to the mentoring and community involvement of their peers and the people that have preceded them in their careers, to help persuade them to change their minds and major in science.

Now, obviously, in summary, no single program is the answer. The young American scientist summer camp program is an answer. I personally believe that this program will help turn our situation around and that DOE has the best blend of experience across the range from the practical to the basic research to produce the desired outcomes.

Now, the students, if this program proceeds as authorized by you and the money appropriated by the Congress, the students who will turn to and be turned on by science by this program will in fact be the first Ph.D's that can get their Ph.D's at the superconducting supercollider. They will in fact be the same people who will get their Ph.D's working on the human genome program.

Last, I find myself unable to resist perpetuating the calculations of time here, this program requires the expenditure per student of one-thirtieth of a second of Federal expenditures to fund these people. I think it's a worthwhile investment.

[The prepared statement of Dr. Wohlpart follows:]

YOUNG AMERICAN SCIENTISTS SUMMER CAMP PROGRAM

Oak Ridge Associated Universities

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YOUNG AMERICAN SCIENTISTS SUMMER CAMP PROGRAM

EXECUTIVE SUMMARY

The Young American Scientists Summer Camp program envisions a network of federally sponsored summer science camps on college and university campuses where high school students will explore the exciting world of science and engineering. Now, as never before, our nation faces a potentially critical shortage of skilled scientists and engineers, at a time when we can least afford it. Congress can play a leading role in solving this problem by reaching out to tap two of our greatest resources: the American academic community and our young people.

The American academic community represents an unparalleled wealth of resources, both in terms of educational research equipment and facilities and in terms of professionals who are not only skilled educators but also world class scientists and engineers. The university network established by the Young American Scientists Summer Camp program will involve colleges and universities with ongoing, energy-related research joined in a common effort to encourage high school students to enter the science and engineering career "pipeline." Additionally, the program will address the important issue of the underrepresented minorities--blacks, Hispanics, women, and the handicapped--in science and engineering. The program is designed to "open the eyes of America's young people" to the importance of science and technology in our lives today and to give them a chance to experience first-hand the excitement of research. In these science camps, students from across the nation will team with role models who are working members of the scientific research community, and together they will learn by actively exploring science and engineering. At the same time, students will be given the tools and information they need to make informed career decisions.

The academic institutions and regional communities participating in the Young American Scientists Summer Camp program will serve as portals into the science pipeline, affecting not just the students who make a choice to become research professionals, but also their fellow students, parents, and community members who stand to become more scientifically literate through their involvement in the program. In the end, the entire country will be served. Central to the concept of the Young American Scientists Summer Camp program is the idea of community involvement where parents, private industry, local school systems, and colleges and universities will be linked together to teach and influence these young people.

The proposed program will establish a federally sponsored network of colleges and universities conducting one- to two-week summer science camps for high school students. The institutions will build a program of exciting and challenging activities involving the students in hands-on science and engineering activities led by university faculty members and by other research professionals in the community. The end result will be the establishment of a number of academic centers around the country joined together for the common purpose of generating enlightened enthusiasm for science among the nation's youth.

YOUNG AMERICAN SCIENTISTS SUMMER CAMP PROGRAM

I. BACKGROUND

A. HUMAN RESOURCE ISSUES

Our nation is rapidly approaching a time when the supply and demand for scientists and engineers will be critically out of balance. Recently, Dr. Bassam Z. Shakhashiri, director of the National Science Foundation's Science and Engineering Education Directorate, warned:

> If one projects through the year 2000, the cumulative shortfall in the holders of BS degrees in natural science and engineering is estimated to be about 430,000--with a similar shortfall of about 8000 PhDs by the year 2004. Colleges already competing with industry for PhDs will face a faculty shortage as some 40 percent of the present science and engineering faculty retire over the next 10 years, and students are turning away from science and engineering careers. (Chemical & Engineering News, August 22)

Unless firm and far-reaching measures are taken, we can expect a shortage of scientists and engineers in a relatively short time. If current trends continue, NSF (1988) projects that of the roughly four million students who were high school sophomores in 1987, only 1.4 percent will complete master's degrees in science or engineering fields; fewer than 0.25 percent will complete science or engineering PhDs.

Scientists and engineers currently comprise four percent of the American work force. The number of science and engineering positions is growing three times faster than total U.S. employment (NSF Human Talent 1987). At the same time, the college-age population is declining. By the early 1990s, the share of undergraduate students majoring in science and engineering fields must increase by 50 percent simply to maintain the number of science and engineering baccalaureate degrees granted in 1984.

Scientists and engineers have specialized skills vital to the nation's economy and international competitiveness. They are heavily involved in research and in the application of research results to technology development. Scientists and engineers who teach are vital to the continued flow of well-trained technical workers and to the general education of the next generation of U.S. citizens who will, as the voting public, make our decisions.

Unfortunately, the current trend for maintaining the supply of these professionals is moving in the wrong direction. There is considerable concern over the quantity and quality of students currently preparing for future positions in science, mathematics, engineering, and other technical fields. The percentage of white males majoring in science and engineering is declining, and after a decade of growth the proportion of women and minority students choosing paths leading toward technical degrees has leveled off. The number of doctoral degrees in science and engineering earned by U.S. citizens has decreased by 50 percent in this decade, and in many technical fields more than half the PhDs granted by U.S. universities go to foreign nationals who are frequently prohibited from remaining in the U.S. by immigration laws. Most disturbing of all, international comparisons of secondary school students place the United States behind most other developed nations in comprehension of technical material.

Innovative approaches and new intervention strategies must be implemented if these trends are to be reversed. A greater proportion of students, both from the group of white males, which has historically produced large numbers of scientists and engineers and from the groups that have been historically underrepresented in technical careers, must be persuaded to enter the science and engineering "pipeline." After extensive reviews of the literature, both the Office of Technology Assessment (1988) and the Government-University-Industry Research Roundtable (1987) concluded that intervention programs for high school students are effective. They are successful in "accelerating the development of students generally and in meeting goals for increased participation of underrepresented groups" (Roundtable 1987). Extracurricular programs that involve hands-on exposure to science are found to be particularly effective.

B. REVIEW OF CURRENT PROGRAMS

While many strategies exist for responding to the concern over future supplies of scientists and engineers, such programs are often underfunded and limited in scope. A recent ORAU review of programs available for junior and senior high school students indicates that there are few opportunities for the average student to experience science first-hand and to interact with scientists and engineers who could serve as career role models.

For example, of the 388 residential programs listed in Science Services' 1989 Director of Student Science Training Programs for High Ability Precollege Students, less than 150 offer an opportunity for hands-on activities. Of those 150 programs, about 40 are limited to local residents or minorities. Of the approximately 100 remaining programs, only 40 are either free or relatively inexpensive---students participating in the other 60 programs pay fees ranging from $300 to $3200. This translates into about 2,020 positions available annually for students to experience science for an average of 23 days.

However, even these 40 programs are limited to the "academically talented" student. Average American precollege students currently have few opportunities to become involved in hands-on research programs which would equip them to assess their interest, aptitude, and abilities in science and engineering fields.

Several national programs provide opportunities for precollege students. The U.S. Department of Energy (DOE) has sponsored programs for precollege students for a number of years. The U.S. Department of Energy's Prefreshman Engineering Program involves about 2000 minority students annually in engineering experiences on college and university campuses. A second DOE minority precollege program is a regional pilot program called the Minority Challenge Program. Unique in its long-term support for and strong involvement with the students and parents, the Challenge program is described in greater detail in Appendix A. DOE's High School Science Student Honors Research program annually places 312 academically talented students in national laboratories for collaborative research participation, and publishes a quarterly High School Science Student Honors Newsletter; there is no cost to the students for participation in this program.

The National Science Foundation (NSF) Young Scholars Projects began in the summer of 1988 with 2500 students, and projects approximately 4700 total students annually will participate in a variety of programs emphasizing hands-on research experience. NSF funds the pilot projects for two-year periods.

The National Aeronautics and Space Administration (NASA) Space Camp program is among the most popular and successful programs. Students from fourth grade through high school may participate in one-week sessions throughout the year. About 15,000 students participated in the 1988 program. Participant costs depend on grade level and time of year.

The federal emphasis on minority science and education programs in recent years has resulted in the availability of free or low-cost research opportunities for a number of minority high school students. In addition to the Department of Energy PREP and Challenge programs described above, the National Action Council for Minorities in Engineering (NACME) produces a directory of precollege engineering programs for under-represented minorities. The directory lists about 90 programs offering only courses to about 13,000 minority participants annually; the courses are free to qualified participants. The National Institutes of Health (NIH) Minority High School Student Research Apprentice Program places about 1000 minority students annually for research experience on university campuses. NASA sponsors a no-cost Summer high school Apprenticeship Research Program open to minority students with good academic records. This NASA program offers research opportunities to about 170 minority students per year; the students must live near a NASA facility.[1]

II. PROGRAM ADMINISTRATION

A. SELECTION OF FEDERAL SPONSOR

In choosing a federal sponsor for the Young American Scientists Summer Camp program, there are several important considerations. The sponsoring agency should have a strong commitment to science education reflected in experience with science education-related programs at many levels.

The sponsoring agency should have strong ties with the academic community, with well-established collaborative linkages to colleges and universities nationwide. This will serve as a solid foundation for the implementation of the proposed program, and the sponsor's ties to the academic community will, in turn, be strengthened. Additionally, the program should complement and expand existing programs of the sponsoring agency.

The agency selected should be available for a relatively long-term commitment to the program, as opposed to a pilot program. As noted in the background section, a longitudinal approach is required for successful intervention; the impact of the program may not be tangible for several years, when the high school junior who participates in 1989, for example, earns a master's degree in 1995 or a doctor's degree in 1998. Additionally, the attention of the general public on science and engineering which will potentially be generated by this program can result in a more literate and technologically aware citizenry only if the program endures.

A fourth important qualification for the potential sponsor is a direct, vital interest in the quantity and quality of the science and engineering work force. An R&D agency dependent on an adequate supply of appropriately trained professionals to accomplish its objectives would best serve the achievement of the program's goals. A variety of federal agencies meet these criteria.

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[1] NASA sponsors an additional precollege program for younger students (5th-8th grades) which does not offer hands-on research or courses considered in this study, but which does offer exposure to science and engineering careers. The Urban Community Enrichment Program provides a three-day enrichment presentation for students from two to three selected urban areas. Fifty-seven middle schools participate; these schools have a high proportion of minority students.

B. OAK RIDGE ASSOCIATED UNIVERSITIES AS ADMINISTRATOR

Oak Ridge Associated Universities (ORAU) will serve as the central program administrator for the Young American Scientists Summer Camp program. Since its formation in 1946, Oak Ridge Associated Universities has been involved in the education and training of scientists and engineers. As a not-for-profit consortium of 49 colleges and universities and a management and operating contractor for the Department of Energy, ORAU develops and administers programs that provide special technical education and training opportunities for students, teachers, university faculty, and postgraduates. (Section VI below provides additional information on ORAU's related experience.)

ORAU, by the nature of its organization, its linkages to the academic and educational communities, its contract with DOE, and its experience and capabilities in creating, operating, and evaluating educational programs, is well suited to manage the summer science camp program. ORAU will advertise the program nationally, prepare and distribute program announcements, convene an academic advisory committee to establish program policies and guidelines, prepare and distribute university/college proposal preparation materials, receive and process university/college applications, convene a review committee to assess the merits of university/college proposals, enter into funding contracts with universities/colleges, assist universities/colleges in advertising their programs and recruiting students, evaluate and assess the programs at universities/colleges, and follow students through attainment of the baccalaureate degree.

The plan described in Sections III and IV below is based on ORAU's 44 years of experience.

III. OBJECTIVES

The principal purpose of the Young American Scientists Summer Camp program is to significantly enlarge the pool of students pursuing science and engineering careers. More specifically, the program will establish a national network of summer science camps where high school students will gain first-hand experience with science and mathematics. Participants will enjoy the sense of discovery inherent in carrying out research through hands-on science activities. They will meet and interact with dedicated and enthusiastic role models, receive career counseling, be exposed to college life, visit science and engineering laboratories, discuss the scientific process and its role in technological change, and consider ethical questions associated with scientific research.

Participants in the program will see modern scientific equipment and facilities and will learn how they are used to solve advanced scientific questions that affect everyday life and pressing national issues. Most importantly, participants will conduct experiments and meet with individuals important to advanced scientific research.

Many national strategies exist for responding to the concern over future supplies of scientists and engineers. At the secondary school level, the focus is on enlarging the pool of students who have the background and interest to pursue science and engineering degrees in college. After a comprehensive review of programs, the Office of Technology Assessment (1988) identified direct contact with research professionals and early involvement in hands-on activities as important factors associated with interest in science and engineering. The Task Force on Women, Minorities, and the Handicapped in Science and Technology, in a report entitled Changing America: The New Face of Science and Engineering (September 1988, p. 5) stated that, "Effective local intervention programs are demonstrating that young people from underrepresented groups can become quality scientists and engineers. However, such programs are too isolated and underfunded to meet national demand."

From this perspective, the following objectives have been identified for the proposed Young American Scientists Summer Camp program:

- to encourage young people from all segments of society to enter the science and engineering pipeline;
- to provide high school students with the academic tools they need to assess their own abilities and aptitudes for science and engineering careers;
- to supply young people with information about careers in science and engineering, providing exposure to role models, tours of facilities, and actual hands-on experience in science;
- to produce a more informed and scientifically literate citizenry; and

Intervention in the educational process is needed to encourage greater numbers of students to seek careers in technical areas. The program described below is modeled after other programs administered by Oak Ridge Associated Universities (see section IV below) and is designed to meet the preceding objectives.

IV. PROGRAM DESCRIPTION

A. GENERAL

The Young American Scientists Summer Camp program is designed to educate a large number of high school students through a national network of summer science camps that will encourage and nurture interest in science, mathematics, and engineering careers. The program will establish science camps at colleges and universities to enlarge the pool of scientifically literate young people who are more likely to make educated choices for careers in science and engineering.

The summer science camp program will consist of one- or two-week summer sessions at universities and colleges throughout the country. Each camp will accommodate between 40 and 50 students; the estimated 20 camps will reach about 1000 students annually. Academic institutions will compete nationally for funding to administer summer science camps. (See Appendix A for a brief summary of a similar ORAU-administered activity, the Minority Challenge Program.)

B. INSTITUTIONAL ELIGIBILITY

Any accredited four-year institution of higher education in the United States will be eligible to submit an application for funding to participate as a science camp center.

(Options: (1) Institutional participation could be limited to academic institutions with a certain level of Department of Energy R&D funding. Exposure of students to energy R&D could then be an integral part of the program. (2) Another possibility is to limit eligible academic institutions to a particular geographic region. We recommend against this restriction.)

C. STUDENT ELIGIBILITY AND BENEFITS

Each Young American Scientist must be a U.S. citizen or permanent resident alien and must be a high school student who has taken at least one high school course in science. The program will be open to students who have expressed clear interest in science and engineering, as well as to those who are unsure about their interest or who have had minimal exposure to science and engineering. The interest of the first group will be deepened, while the interest of the second group will be encouraged and nurtured.

Students will receive free room and board while on campus. At the conclusion of the camp session, each student will receive a Certificate of Participation recognizing the successful completion of the program. Oak Ridge Associated Universities will encourage the granting of credit or recognition by students' high schools. Additional honors are described in Section D, Special Recognition.

(Options: There are several considerations with respect to the educational level of participating students. Participation during the senior year may be too late to influence career decisions. If students are not old enough and do not have the necessary academic background, they may not benefit from the experience. Each institution will determine its own age limitations, and the grade level requirements of the camps may vary from site to site.)

D. SPECIAL RECOGNITION

Staff members from each program will select a student as "Outstanding Young Scientist." The selected students will be flown to Washington, D.C., for an awards ceremony, to meet with the House Science, Space, and Technology Committee members. They will participate in tours and other activities. All students will receive a special letter of honor from the President's Science Advisor (or other appropriate official) in recognition of their participation and achievements.

E. SELECTION OF SCIENCE CAMPS

A detailed program announcement will be prepared and distributed nationally to solicit applications from eligible academic institutions. Institutions interested in hosting a summer science camp will be required to submit an application describing the nature of the program they plan to implement, available facilities, qualifications of the staff, program cost, arrangements with local schools and industries, and details of the instructional and hands-on components. A sample curriculum is shown in Appendix B.

Applications will be reviewed by a panel of senior educators, scientists, and engineers. The panel will provide a ranking of applications based on the scientific and educational merit, the experience of the staff, costs, and the nature of the program. (This peer review system with selection based on merit will ensure high-quality experiences). Final selection of science summer camps will be made by the sponsoring agency.

Universities and colleges applying for funding will be required to demonstrate substantive involvement of local schools, R&D industries, and federal R&D laboratories. The evaluation process will include criteria that measure the quality and extent of these linkages.

F. ADVERTISING

Advertising will take place on both national and local levels. At the national level, an advertising campaign will alert colleges and universities across the country to the program and will invite them to submit an application. Program information will be disseminated through a variety of media (i.e., journals, news releases). High schools throughout the country will be informed of the program through targeted mailings and announcements at professional meetings, and interested students will be invited to request an application. At the regional level, participating academic institutions will recruit from area high schools and surrounding communities.

G. STUDENT SELECTION

Each academic institution will select the students to participate in its program. Selection will be based on criteria described in its application but should include teacher references, student career interests as described in a required essay, grade point average, and courses taken.

H. MINORITIES, WOMEN, AND HANDICAPPED

Special recruitment efforts will be made to encourage applications from minorities, women, and the handicapped. Academic institutions will be encouraged to consider special programs for these groups. Minority academic institutions will be encouraged to submit applications to sponsor science camps.

I. INVOLVEMENT OF LOCAL SCHOOLS, INDUSTRIES, AND FEDERAL LABORATORIES

The Summer Science Camp program will serve as a unique mechanism for linking universities with local schools and private and federal R&D facilities. The common interest in students can serve as a catalyst to create linkages between universities and research laboratories.

Universities and colleges making application for funding will be required to demonstrate substantive involvement of local schools, R&D industries, and federal R&D facilities in planning the programs. Local schools will be involved in all aspects of the summer science camp. Teachers will assist in planning, serve as "mentors" to students, teach appropriate laboratory and lecture sessions, and accompany students on tours of scientific facilities.

Academic institutions hosting a summer science camp will be required to demonstrate continued involvement with local schools during the academic year. This involvement may include university faculty visits to schools, assistance in science fairs and science fair projects, campus visits, involvement of teachers in research, faculty and community members voluntary service as mentors to individual students or groups of students, providing laboratory demonstrations, or assisting in curriculum improvement.

The involvement of industries and federal laboratories may take a variety of forms. Involvement both in the summer science camp and in academic-year activities will be encouraged. Industries and federal laboratories can host student visits, demonstrate state-of-the-art facilities and equipment, lend instrumentation to schools, provide lecturers, or assist in science fairs and science fair projects. In addition, staff scientists can serve as "mentors" to students.

J. EVALUATION AND FOLLOW-UP

The Young American Scientists summer camp program will be evaluated by ORAU as program administrator at all stages. Information will be collected from participants as they enter and exit the program, and from staff members regarding the overall program. This will be compared to information collected periodically after students have returned to school to determine the extent to which the program objectives are met. Of particular interest will be whether or not past participants enter college and pursue science, mathematics, or engineering degrees.

The procedures followed in collecting and assessing information provided by participants and their teachers will build on years of experience in evaluating education and training programs. Special attention will be given to courses taken, expected major field, and highest degree expected. Responses of past program participants will be compared to those of other typical students as reported in major national studies.

As program administrator, Oak Ridge Associated Universities will visit summer science camp sites and interact with the staff and students. Information will be collected on overall operations, and comparisons will be made to determine the most effective program elements. This information will serve as the basis for altering future procedures and site selection criteria.

Each year a report will be prepared that summarizes program operation and evaluation activities. After two years, a preliminary assessment report will be completed based on follow-up information collected from past participants. This report will be updated each year based on new data. Over the years it will be possible to trace the educational progress of past participants and determine the extent to which participation in a summer science camp has influenced educational plans and career activities.

V. COST/NUMBER OF UNIVERSITIES/NUMBER OF STUDENTS

The estimated cost of a two-week science summer camp for 50 students is between $45,000 and $50,000--or $500 per student week. This cost includes: room and board for students; faculty and staff salaries; expendables, advertising, indirect and program operating costs. (Note: Students do not receive a stipend or travel reimbursement.) In addition, the trip to Washington, D.C., for the 20 Outstanding Young Scientists average $500 per student for round-trip travel, lodging, and per diem, a total of $10,000.

Thus, an annual budget of $1 million, will support about 20 two-week summer science camps and reach about 1000 students each year.

VI. OAK RIDGE ASSOCIATED UNIVERSITIES

A. GENERAL BACKGROUND

Oak Ridge Associated Universities (ORAU) has been an operating and management contractor for the U.S. Department of Energy (DOE) and its predecessor agencies for more than 40 years. ORAU is a consortium of 49 southeastern colleges and universities, and a not-for-profit corporation. ORAU administers education and training programs for DOE, NSF, and other federal agencies; conducts research in health sciences, energy policy, and human resource management; and provides technical assistance to DOE and other federal agencies. As a university consortium, ORAU is closely aligned with the academic community; as a management and operating contractor to DOE, ORAU is well situated to administer national programs for DOE. This dual "personality" qualifies ORAU in a unique way to design, implement, manage, and evaluate the proposed Young American Scientists summer camp program.

B. RELATED PROGRAM EXPERIENCE

In the summer of 1988, ORAU initiated with DOE funds the Challenge Summer Science camp and academic year program for minority high school students described in Appendix A. Many aspects of this program will serve as a model for the proposed summer science camps.

For four years ORAU administered and evaluated the U.S. Department of Energy "Faculty Development Projects in Energy Education." The program was designed to enhance energy education in classrooms throughout the country. Vehicles for achieving this objective were summer institutes and workshops at university and college campuses. Between 1979 and 1983, the program reached an estimated 16,000 elementary, high school, and college teachers.

For many years ORAU operated mobile energy education programs for high school students dealing with specific energy technologies. Funding was originally provided by the U.S. Department of Energy and later by the private sector, principally utility companies. This popular program reached an estimated three million high school students and members of civic clubs annually and was noted for its innovative, interactive teaching methods.

In 1985 ORAU assisted DOE and the Lawrence Livermore National Laboratory in establishing the DOE High School Honors program. Fifty high school students participated in a two-week summer program at the laboratory. The program has since been expanded to six DOE national laboratories. ORAU continues to provide DOE with technical support for this national program.

ORAU is coordinating the development of energy education curriculum materials for elementary and high schools, currently focusing on the carbon dioxide/greenhouse effects issue.

With funding from the National Science Foundation, ORAU initiated a science and mathematics teacher enhancement project in 1986. The project involves high school teachers in energy-related research at federal, private, and university research facilities.

ORAU administers educational and training programs exceeding $11 million per year for DOE and other federal agencies. ORAU is uniquely qualified through its involvement in energy education and its close working relationships with the academic community to develop, implement, administer, and evaluate the national summer science camp program.

VII. ACADEMIC ADVISORY COMMITTEE

The advice of the scientific, academic, and education communities in designing and implementing this program is essential to ensure its educational effectiveness and quality. An advisory committee of senior scientists and educators will be convened at an early stage to assist in developing program guidelines and policies. This group will also review the merit of and assist in the selection of institutional programs.

VIII. SCHEDULE

A model schedule, closely tied to the academic calendar, is outlined below. This schedule is somewhat flexible and can be modified.

September	* Receive authorization to implement program
October	* Prepare academic institution program announcement and application package
	* Convene advisory committee to review policies, procedures, and application materials
	* Advertise program nationally
January	* Review institutional applications
February	* Announce awards
	* Advertise program nationally for student participation
April	* Selection of students completed
June-July-Aug	* Summer Science Camps
	* Staff visits to selected science camps
September	* Evaluate/assess summer science camps
October	* Prepare Annual Report
	* Initiate next cycle

APPENDICES

APPENDIX A

MINORITY CHALLENGE PROGRAM IN SCIENCE AND ENGINEERING

PILOT PROGRAM

August 1988

Summary

In the summer of 1988, Oak Ridge Associated Universities (ORAU) successfully piloted the Challenge Summer Science Camp, one of the components of the **Minority Challenge Program in Science and Engineering**. The outcomes of this pilot effort were gratifying and not only generated organizational enthusiasm for the project, but also earned praise from area scientists, educators, government officials, parents, and--most important of all--from the students themselves. The program was highly visible in the community, receiving a great deal of attention from the media.

The Minority Challenge Program in Science and Engineering provides long-term support, both scholastic and financial, which will increase the number of minority students who pursue undergraduate and graduate degrees in science and engineering. Based on the premise that early commitment to a science career is essential to achieving this goal, Challenge reaches back to the junior high school level to identify students with interest in and aptitude for science. Through a prescribed system of mentoring, enrichment activities, exposure to career role models, summer and academic-year activities, research internships, and college scholarships, these students are nurtured from the early precollege years through the attainment of a baccalaureate degree, and through graduate school in certain cases. The Challenge concept (1) establishes a strong network of regional schools, public and private research facilities, and colleges and universities; and (2) creates a strong partnership of individuals--scientists, educators, students, and parents--all committed to the long-term goal of bringing minority students into the science and engineering pipeline. The united efforts of the Challenge team will give these young people the resources of confidence, knowledge, and financial support they need to succeed.

Following are highlights the accomplishments and major activities of the 1988 pilot Challenge Summer Camp.

PROGRAM STATISTICS

Number of applications reviewed		74
Number of appointments made		30
Number of parents attending events	50-60	

PARTICIPATING SCHOOLS/ORGANIZATIONS 11

PROGRAM HIGHLIGHTS

Welcome and Challenge, Tyrone Crider
  (Member of Jesse Jackson's Campaign Staff)
Algebra Workshop
Laboratory experience in radiation health physics, chemistry
  (5-day series)
Career Awareness/Interest Evaluation Workshop
SAT/ACT Workshop
Financial Aid Workshop
Computer Workshop at State Technical Institute
Overnight visit to Atlanta University and Georgia Tech campuses
Tour of ORNL reactors
Tour of University of Tennessee campus (emphasis on laboratories)
Tour of American Museum of Science and Energy
Tour of Radiation Emergency Assistance Center/Training Site
  (REAC/TS)
Tour of Maxima (minority-owned R&D contractor)
Informal "rap sessions" with guest scientists

Social/cultural events: Orientation reception, picnic, visit to Martin Luther King Memorial, swimming party, rock concert, shopping spree in an Atlanta mall, group meals at local restaurants, pizza party, barbecue

Appendix B

YOUNG AMERICAN SCIENTISTS SUMMER CAMP PROGRAM

SAMPLE CURRICULUM

A. LABORATORY EXPERIENCE

Radiation Health Physics
Chemistry
Radiobiology
Environmental Sciences
Physics
Mathematics and Computers

B. SPECIAL TOPIC WORKSHOPS

How to Write a Research Paper
Aptitude testing and discussion/interpretation of results
Introduction to use of libraries for research (university library)
Preparing for college entrance exams

C. INTERACTIVE DISCUSSIONS

The Scientific Method
Careers in Science
Current Topics in Biology
Science and Society
Philosophy of Science
Current Topics in Agriculture
Current Topics in Engineering
Ethics in Science
Current Topics in Physics
Current Topics in Chemistry
Current Topics in Geosciences
Mathematics and Computers

D. TOURS

Campus laboratories
Local private R&D industries (include minority-owned R&D firms)
Federal laboratories and other government research facilities
Unique campuses (i.e., agriculture campus) which belong to university systems
Visits to other area campuses and laboratories
Regional minority colleges (historically black or hispanic colleges)

REFERENCES

Energy Research Advisory Board. July 1988. Science and Engineering Education.

Government-University-Industry Research Roundtable. 1987. Nurturing Science and Engineering Talent. National Academy of Science. Washington, D.C.

National Science Foundation. 1987. Human Talent for Competitiveness.

National Science Foundation. 1988. Personnel in Natural Science and Engineering. Working Draft prepared by the Division of Policy Research and Analysis. Washington, D.C.

Office of Technology Assessment. 1988. Educating Scientists and Engineers--Grade School to Grad School. OTA-SET-337. Congress of the United States. Washington, D.C.

The Task Force on Women, Minorities, and the Handicapped in Science and Technology. September 1988. Changing America: The New Face of Science and Engineering.

Worthy, Ward. 1988. "NSF Official Urges Commitment to Improve Science Education." Chemical and Engineering News. August 22, 1988.

Mr. **Boucher**. Thank you, Dr. Veigel.

Dr. Peddicord?

STATEMENT OF LEE PEDDICORD, ASSISTANT DIRECTOR FOR RESEARCH, TEXAS ENGINEERING EXPERIMENTAL STATION, TEXAS A&M UNIVERSITY

Dr. **Peddicord**. Thank you, Mr. Chairman.

I am appearing today in my role as the Chairman of the Nuclear Engineering Department Heads Organization. NEDHO is a national organization composed of the academic leaders in nuclear engineering and applied nuclear sciences at the colleges and universities in 27 States around the country.

Today I would like to touch briefly on four points. First, I would like to express the appreciation of the academic community for the vision and leadership of this committee which has resulted in the allocation of $5 million in fiscal year 1988 and $6 million in fiscal year 1989 for nuclear engineering university programs. These funds are administered by the DOE office of university programs under the able direction of Dr. Richard Stevens and the results have had an extraordinarily positive and invigorating impact.

The appropriation has resulted in additional DOE nuclear engineering and health physics gradu~~ate fellows~~hips, has increased the support of minority institutions, and has led to an expansion of the extremely effective DOE reactor sharing program.

However, perhaps the most exciting aspect has been the notice of program interest managed by the Idaho National Engineering Laboratory, which has allows faculty and students to conduct research on innovative new ideas in the nuclear engineering field. Last year, over 160 proposals were received, 34 were classified in the must-fund category. And 18 projects were supported at 14 universities.

The announcement for the current year's program has just appeared. This program is extremely important because it provides an opportunity which up to now has not existed for faculty to explore long-term innovative ideas which could have a great future impact in applied nuclear science and nuclear engineering.

In this respect, it is important to note that while nuclear engineers are heavily involved in the commercial light-water reactor industry, in fact as much or more of our attention goes to the whole broad scope of utilization of nuclear forces and nuclear processes for engineering applications.

In fact, many of our graduates are involved in the engineering aspects of the type of projects that were discussed this morning concerning high-energy accelerators.

The current DOE program authorized by the committee permits faculty to investigate new research ideas covering the entire spectrum of nuclear engineering activities. In addition, the projects can be performed over two to three years, which allows students to complete their Ph.D. programs as part of the research.

We very much appreciate the committee's initiatives such as led to the establishment of this program that has had an extraordinarily beneficial effect. We request that the committee, as you have done in the past, to again authorize $10 million for fiscal year 1990 for the DOE office of energy research's nuclear engineering university program.

Secondly, I would like to specifically comment on the DOE graduate fellowship program. These fellowships allow U.S. citizens who might not otherwise be able to pursue graduate degrees to embark directly on Ph.D. programs. The DOE fellowships complement a number of other programs such a those from the Institute for Nuclear Power Operations and the American Nuclear Society, which primarily aid students to gain their master's degree. This corresponds more closely to commercial industry's needs.

In contrast, the DOE fellowships play a critical role because they focus at the doctoral level. As you know, of the 97 Ph.D.'s awarded in nuclear engineering and health physics, less than one-half went to U.S. citizens, and this number did not approach the personnel needs of even the Federal laboratories.

This year, the congressional funding has resulted in the award of ten additional fellowships. I would ask the Committee to urge DOE to continue to focus on the support of Ph.D. programs in order to meet the research needs in nuclear engineering and health physics.

Third, I would like to call the committee's attention to the recent study by the National Academy of Sciences and the National Research Council entitled "University Research Reactors in the United States, Their Role and Value." The study was chaired by Dr. David Shirley of the Lawrence Berkeley Laboratory, who testified earlier.

I believe the decline to 36 university facilities, which is one-half of the original number, is cause for great concern. This is especially serious, in my view, because the university research reactors are a critical component in our overall national research infrastructure.

While the nuclear engineering programs use these reactors for both curriculum and research needs, it is imperative to recognize that the university reactors serve a much broader research community than just nuclear engineering. Faculty from other engineering disciplines, the physical and natural sciences and medicine carry out extensive research at these facilities.

Further erosion in the number and status of university reactors would negatively impact our national capability to perform research in many high-technology areas. Other countries have recognized this need and responded vigorously. The situation has reached the point where our national laboratories often now have to recruit overseas to find qualified experimentalists who have research reactor experience.

The National Research Council identified an annual need for $20 million for funding to keep the facilities and equipment up to date. I would urge the committee to discuss the situation with Dr. Marcus Voth and Dr. Otto Harling of the Test Research and Training Reactor Society. Dr. Voth is here today. He is from Penn State University. He is accompanied by his daughter Sarah, who is a freshman at State College High School. She is in the back of the room cramming for her algebra test which takes place tomorrow. But she is seeing our Government in action.

I would like to point out it might be worthwhile to hold some discussions with the American Physical Society, the Materials Research Society, the American Association for the Advancement of Science, and other groups which represent the full breadth of users of research reactors. While nuclear engineering represents only one segment of this community, NEDHO is very supportive of the university reactors and would feel that if the committee sees fit, it would be entirely appropriate for additional funds to be authorized under the nuclear engineering university program for these facilities.

I would only request that the committee provide guidance as to the utilization of any authorized funds between the academic programs and the facilities.

To address these items, I have attached to my testimony an outline of a budget of fiscal year 1990 of $15 million to accommodate both the academic and reactor programs. This would include $1 million for the fellowship program, $800,000 for minority university programs, $800,000 for a new DOE traineeship program, $2.4 million for continuing reactor research projects approved in prior years, $5 million for new research projects, $1 million for an expanded reactor sharing program, and $4 million for reactor operations and equipment modernization and upgrade.

Finally, if I could, I would like to introduce to the committee Steven Hayes from Abilene, Texas. Mr. Hayes is a graduate student in nuclear engineering at Texas A&M and holds a DOE graduate fellowship.

In addition, as an undergraduate Mr. Hayes was supported as an hourly student employee on a DOE research project and was also a national finalist for one of the National Science Foundation creativity awards. One of the reasons he didn't get it is he was too young at the time.

His research is in the area of the performance of advanced fuels and materials for space reactor applications, and is a co-originator of the activated heat source concept, which is a particularly exciting idea which could have a revolutionary impact on the utilization of space nuclear power by enhancing launch safety and addressing concerns about placing reactors in low Earth orbit.

Because Mr. Hayes received one of the additional DOE fellowships which were made possible through last year's authorization, I believe the committee can take great satisfaction in knowing that it played an instrumental role in enabling an exceptionally talented and creative young student to work towards his Ph.D. degree.

It will be the innovative young researchers like Mr. Hayes and his colleagues who make the advances in technology that will permit the United States to continue to play a dominant global role.

We all appreciate the committee's pivotal role in making these achievements possible.

I would like to point out, too, that our graduates from these programs often go on to make contributions in other ways. Sitting to your left is a holder of a master's degree in nuclear engineering from Oregon State University, and we are pleased to see her playing a role in the committee's activities.

Thank you very much, Mr. Chairman.

[The prepared statement of Dr. Peddicord follows:]

Testimony

before the

SUBCOMMITTEE OF ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

by

KENNETH L. PEDDICORD

Professor of Nuclear Engineering
Texas A&M University

Assistant Director for Research
Texas Engineering Experiment Station

Chairman of the
Nuclear Engineering Department Heads Organization

February 23, 1989

Madame Chairman, Members of the Committee, my name is Kenneth L. Peddicord and I am a Professor of Nuclear Engineering at Texas A&M University and Assistant Director of Research for the Texas Engineering Experiment Station. I am appearing this morning as the Chair of the Nuclear Engineering Department Heads Organization. NEDHO is composed of the academic leaders in nuclear engineering and applied nuclear science at the colleges and universities in 27 states around the country.

This morning I would like to touch on four points First, I would like to express the appreciation of the academic community for vision and leadership of the Committee on Energy Research and Development which has resulted in the allocation of $5 million in FY88 and $6 million in FY89 for nuclear engineering university programs. These funds are administered by the Office of University Programs at the Department of Energy and have had an extraordinarily positive and envigorating impact. The appropriation has resulted in additional DOE Nuclear Engineering and Health Physics Fellowships, has increased the support of minority institutions, and has led to an expansion of the extremely effective DOE Reactor Sharing Program. However, perhaps the most exciting aspect has been the Notice of Program Interest managed by the Idaho National Engineering Laboratory which has allowed faculty and students to conduct research on innovative new ideas in the nuclear engineering field. Last year over 160 proposals were received, 34 were classified in the "must fund" category, and 18 projects were supported at 14 universities. The announcement for the current year's program has just appeared. This program is extremely important because it provides an opportunity, which up to now has not existed, for faculty to explore long term innovative ideas which could have a great impact in applied nuclear science and technology. In this respect, it is important to note that while nuclear engineers are heavily involved in the commercial light water reactor industry, in fact as much or more of our attention goes to the whole broad scope of the utilization of nuclear forces and nuclear processes for engineering applications. The current DOE program authorized by the Committee on Energy Research and Development permits faculty to investigate new research ideas covering this entire spectrum of nuclear engineering activities. In addition, the projects can be performed over 2 to 3 years which allows students to complete their Ph.D. dissertations as part of the research. We very much appreciate the Committee's initiatives which has led to the establishment of this program; it has had an extraordinarily beneficial effect. We request that the Committee, as you have done in the past, to again authorize $10 million for FY90 for the DOE Office of Energy Research nuclear engineering university program. Attached is a list of funded projects and a NEDHO commentary on the DOE program.

Secondly, I would like to specifically comment on the DOE fellowship program. These fellowships allow U.S. citizens who might not otherwise be able to pursue graduate degrees to embark directly on Ph.D. programs. The DOE fellowships complement a number of other programs such as the Institute for Nuclear Power Operations and the American Nuclear Society which primarily aid students towards the Master's degree. This corresponds more closely to needs of the commercial industry. In contrast, the DOE fellowships play a critical role because they focus on the doctoral level. As you know, last year, of the 97 Ph.D.'s awarded in nuclear engineering and health physics, less than one half went to U.S. citizens and this number did not approach the personnel needs of even the federal laboratories. This year the Congressional funding has resulted in the award of 10 additional DOE fellowships. I would ask the Committee to urge DOE to continue to focus on the support of Ph.D. students in order to meet the research needs in nuclear engineering and health physics.

Thirdly, I would like to call to your attention the recent study by the National Academy of Sciences and the National Research Council entitled *University Research Reactors in the United States--their Role and Value*. I believe the decline to 36 university facilities, which is one-half of the original number, is cause for great concern. This is especially serious because in my view the university research reactors are a critical component in our national research infrastructure. While the nuclear engineering programs use these reactors for both curriculum and research needs, it is imperative to recognize that the university reactors serve a much broader research community than just nuclear engineering. Faculty from other engineering disciplines, the physical and natural sciences, and medicine carry out extensive research at these facilities. Further erosion in the number and status of university reactors would negatively impact our national capability to perform research in many high technology areas. Other countries have recognized this need and responded vigorously. This situation has reached the point where our national laboratories often now have to recruit overseas to find qualified experimentalists who have research reactor experience. The National Research Council identified an annual need for $20 million of funding to keep the facilities and equipment up to date. I would urge the Committee to discuss this situation with Dr. Marcus Voth and Dr. Otto Harling of the Test, Research, and Training Reactor Society. It might also be worthwhile to contact other professional organizations such as the American Physical Society, the Materials Research Society, the American Association for the Advancement of Science, and other groups which represent the full breadth of users of research reactors. While nuclear engineering represents only one segment of this community, NEDHO very much support the needs of the university reactors and would feel that, if the Committee sees fit, it would be entirely appropriate for additional funds to be authorized under the nuclear engineering university program for these facilities. I would request that the Committee provide guidance as to the utilization of any authorized funds between the academic programs and reactor facilities.

To address the items I have discussed, attached to my testimony is a proposed budget for FY90 for $15 million dollars that would include $1 million for the fellowship program, $0.8 million for minority university programs, $0.8 million for a new DOE traineeship program, $2.4 million for continuing research projects approved in prior years, $5 million for new research projects, $1 million for an expanded reactor sharing program, and $4 million for reactor operations and equipment modernization and upgrade.

Finally, I would like to take this opportunity to introduce to the Committee Steven L. Hayes of Abilene, Texas. Mr. Hayes is a graduate student in nuclear engineering at Texas A&M University and holds a DOE Fellowship. In addition, as an undergraduate, Mr. Hayes was supported as an hourly student employee on a DOE research project and was also a national finalist for one of the National Science Foundation Creativity Awards. His research is in the area of the performance of advanced fuels and materials for space reactor applications and he has made a number of contributions to the "activated heat source" concept, an idea which could have a revolutionary impact on the utilization of space nuclear power by enhancing launch safety and addressing concerns about placing reactors in low earth orbit. Because Mr. Hayes received one of the additional DOE Fellowships which were made possible through last year's authorization, I believe the Committee can take great satisfaction in knowing it played an instrumental role in enabling an exceptionally talented and creative young student to work toward his Ph.D. degree. It will be the innovative young researchers such as Mr. Hayes and his colleagues who will make the advances in techology that will permit the U.S. to continue to play a dominant global role. We all appreciate the Committee's pivotal role in making these achievements possible.

Thank you for the opportunity to present these remarks.

Proposed Budget

U.S. Department of Energy
Office of University Programs

Nuclear Engineering University and Reactor Facilities Programs

For FY90

DOE Nuclear Engineering and Health Physics Ph.D. Fellowships	$1.0 million
Minority Institutions Program	$0.8 million
New DOE Traineeship Program	$0.8 million
Ongoing Research Projects (approved in prior years)	$2.4 million
New Research Projects	$5.0 million
Expanded Reactor Sharing Program (to allow for support of projects from faculty members from both inside the host university as well as from other universities in the region which do not have reactor facilities)	$1.0 million
Reactor Operation and Equipment Modernization and Upgrade	$4.0 million
Total	$15 million

NEDHO

Nuclear Engineering Department Heads Organization
301 WERC, College Station, TX 77843-3126
(409) 845-1722

COMMENT ON THE DEPARTMENT OF ENERGY OFFICE OF ENERGY RESEARCH NUCLEAR ENGINEERING UNIVERSITY PROGRAM

In Fiscal Year 1988, Congress appropriated $5 million for nuclear engineering university programs. The program has been managed by the U. S. Department of Energy Office of Energy Research. The appropriations bill directed that the funds be used for "graduate fellowships, direct research support, pass through research support from Department laboratories and contractors, and educational support programs in the field of nuclear engineering".

These funds have had an extremely dramatic and positive impact on nuclear engineering university programs. Ten more awards were added to the DOE Nuclear Engineering and Health Physics Fellowship program. This then allowed a total of 15 U. S. citizens, who might not have otherwise pursued graduate education, to embark on Ph.D. programs.

Of particular excitement to nuclear engineering faculty was the Notice of Program interest issued by DOE in conjunction with the Idaho National Engineering Laboratory which requested proposals for new research projects. This is particularly significant since in recent years few opportunities have existed for nuclear engineering faculty to seek funding to explore innovative advances in nuclear technology. As a result, there was an overwhelming response and over 160 proposals were received. The Idaho National Engineering Laboratory conducted peer reviews of the proposals by university, national laboratory, and government experts. Thirty four proposals were of such high quality that they were classified as "must fund", but money was available for only 18 projects. The range of ideas proposed is extremely diverse and the funded projects address not only current issues in nuclear technology, but emerging ideas as well. A list of the funded programs is appended. The response to the call for proposals indicates not only the level of enthusiasm, but the quality of ideas in the nuclear engineering departments.

Other uses of the $5 million appropriation include $250,000 to initiate an important study by the National Academy of Sciences and the National Research Council on nuclear engineering university programs. Funds were also utilized for the OER minority university program and a further $250,000 was earmarked to augment the DOE Reactor Sharing Program. The Reactor Sharing Program must rank as one of the most successful undertakings of the Department of Energy because it allows faculty from universities with no reactors to utilize existing facilities on other campuses. A wide range of superb research has emerged from this program over the years.

In FY 89, an additional $6 million has been appropriated for nuclear engineering university programs. These funds will go towards continuing programs and permit an expansion of the exploration of new and exciting research ideas. NEDHO also feels that for FY90 the program merits funding at the original authorized level of $10 million.

From the perspective of the Nuclear Engineering Department Heads Organization, the DOE OER program has been immensely successful. It has allowed talented young students to pursue advanced degrees and has enabled faculty members to explore innovative and creative research. The program has had an extremely beneficial impact on nuclear engineering university programs and assures the continuing flow of qualified graduates to meet the nation's needs in nuclear technology related fields.

FY 88 FUNDED PROJECTS

DOE/ER Nuclear Engineering Research Program

W. R. Martin, The University of Michigan, "The Slightly-Enriched Spectral Shift Reactor", $210,000.

E. E. Lewis, Northwestern University, "Variational Nodal Transport Methods for Hexagonal and Three Dimensional Geometries", $55,000.

J. F. Kunze, University of Missouri-Columbia, "Natural Convection Boiling Under Low Temperature and Pressure: Experimental Benchmark Verification", $61,904.

Y. A. Hassan, Texas A&M University, "Multiparticle Imaging Technique for Two-Phase Fluid Flows Using Pulsed Laser Speckle Velocimetry", $94,000.

T. J. Downar, Purdue University, "Advanced Depletion Perturbation Methods with an Application to Waste Transmutation in the Integral Fast Reactor", $36,853.

A. A. Solomon, Purdue University, "Dimensional Microstructural and Compositional Stability of Metal Fuels", $193,000.

J. A. Bernard, Massachusetts Institute of Technology, "Closed-Loop Digital Control of Multi-Modular Reactors", $90,000 (FY90).

R. N. Christensen, Ohio State University, "Development of an Empirical Model for a Steam Driven ECCS for an Inherently Safe Reactor and a Dynamic Methodology for System Reliability Assessment", $125,000.

S. Banerjee, University of California, Santa Barbara, "Thermalhydraulic Aspects of Decay Heat Removal by Natural Circulation in Fast React Systems", $53,000.

B. A.Chin, Auburn University, "Weld Defect and Penetration Control", $163,000.

J. J. Dorning, University of Virginia, "Improved Deterministic Calculational Methods for Irregularly Shaped Shields", $95,000.

B. K. Hajek, Ohio State University, "Installation and Evaluation of a Nuclear Power Plant Operator Advisor Based on Artificial Intelligence Technology", $197,000.

D. T. Neill, Idaho State University, "Siphon Breaker Design", $67,000.

G. H. Miley, University of Illinois, "Experimental Development of Nuclear Pumped Laser Candidate for Next-Step Inertial Confinement Fusion Driver", $75,000.

P. Griffith, Massachusetts Institute of Technology, "Avoiding Water Hammer/Fluid Transients in Nuclear Piping Systems by Controlled Filling", $172,000.

D. R. Harris, Rensselaer Polytechnic Institute, "Fissile Assay of Spent Fuel Using Slowing Down Time Device", $149,000.

R. E. Uhrig, University of Tennessee, Knoxville, "Enhancing Nuclear Power Plant Performance through the Use of Artificial Intelligence", $244,000.

G. S. Was, The University of Michigan, "Irradiation Assisted Stress Corrosion Cracking of Austenitic Stainless Steels", $150,000.

PANEL 4 DISCUSSION

Mr. **Boucher**. Thank you very much, Dr. Peddicord.

Mr. Hayes, we welcome you to the committee and congratulate you on your achievements.

Gentlemen, I just have a couple of questions.

Dr. Veigel, do you have any data or statistics that would suggest that programs such as the young Americans in science summer camp program can be successful in bringing young people into careers in science?

Dr. **Veigel**. Sir, that is an excellent question. I do not personally have an answer, and I will get it for you.

Mr. **Boucher**. We will keep the record of this hearing open for the purpose of your submitting an answer to that question, and I would appreciate your doing so.

[The information follows:]

INTERVENTION PROGRAMS: PROVEN SUCCESSES

WHERE ARE THE INTERVENTION POINTS?

- The 1988 Energy Research Advisory Board to the U.S. Department of Energy *reported in their recent assessment of* Science and Engineering Education that "Along the educational time-line from elementary through graduate school, certain points stand out as "nodes," offering high opportunity for effective interventions in the teaching of science and mathematics."

- A June 1988 working draft from NSF entitled, Personnel in Natural Science and Engineering, discusses the need for intervention strategies to alleviate the expected personnel shortfall in science and engineering. According to this study, phase one is the attraction of students into the pipeline, and phase two is the retention of students who have already become associated with science and engineering. The 40 million students in grades 1-10 are candidates for attraction intervention programs, while retention strategies are aimed at three "nodes"---high school juniors and seniors, undergraduate students, and graduate students.

- We know the key points at which most students in the United States drop off the mathematics-science pipeline. Junior high school is one. The decisions about which mathematics and science courses to take at this time could foreclose choices later (Task Force on Women, Minorities, and the Handicapped in Science and Technology, Sept. 1988, pg. 17).

WHAT STUDIES AND EXPERT OPINIONS SHOW THE PROBABLE SUCCESS OF SUCH INTERVENTION PROGRAMS?

- Effective local intervention programs are demonstrating that young people from underrepresented groups can become quality scientists and engineers. However, such programs are too isolated and underfunded to meet national demand (Task Force, 1988, pg. 5).

- Intervention programs, if replicated with care and given stable funding, can make a difference. For example, the Comprehensive Math and Science Program (CMSP) in New York randomly selects students in 9th grade and, using in-service teachers, offers them four years of college preparatory mathematics, including calculus. . . . On New York State Regents mathematics exams taken in 1987, twice as many CMSP students as non-CMSP students passed (Task Force, 1988, p. 21).

- The Math, Engineering, and Science Achievement (MESA) programs in the western United States have experienced significant success in working with hispanic students. This program establishes a partnership with universities, high schools, and industry to identify talent, offer tutoring and counseling, encourage parental involvement, and provide mentors for participants. Of the 4,000 students who participate annually, about 90 percent go on to college, and 66 percent major in science and engineering! (Task Force, 1988, p. 46).

- **Evaluations and assessments of intervention programs and activities show that such efforts and activities can be effective. Effort to encourage science and engineering talent have been documented to**

    - **alter stereotypes,**
    - **revitalize teachers,**
    - **increase math and science course taking,**
    - **improve academic achievement,**
    - **crystallize students' interests,**
    - **stimulate matriculation in higher education,**
    - **improve retention of underrepresented groups,**
    - **stimulate interest in research careers,**
    - **raise faculty expectations; and**
    - **increase numbers of graduate students.**

    The attached pages list 14 intervention programs and highlights of their measurable impacts on participants (Government-University Research Roundtable, 1987, pp. vi, 34-38).

- Mathematics preparation, hands-on laboratory and field experience, research participation, teachers' high expectations, high-quality teaching, and placement in the academic curriculum track or in a science-intensive school are correlated with interest in majoring in science or engineering in college (OTA 1988, pg. 23).

Follow-up assessments of DOE programs demonstrate that intervention programs have a significant impact on the educational accomplishments and career plans of past participants. For example, DOE's High School Science Students Honors Program has been shown to encourage participants to go on to pursue science and engineering degrees in preparation for professional careers in research. Over 40 percent of participants indicate later that the program influenced or changed their course of study in college and over half said the program changed their career goals. More than 80 percent expressed interest in working in a federal research laboratory after completing school.

Information collected from individuals who participated in the DOE Student Research Participation Program also indicate that laboratory research programs can have a significant impact. For example, 60 percent of those who participated in the program between 1979 and 1982 indicated that the program influenced their decision to attend graduate school. More than 55 percent said that the program influenced their choice of area of specialization, and former participants were found to be three times as likely as other scientists and engineers to be working in a federal research laboratory after completing school.

The evidence provided by these and other programs supports the hypothesis that intervention activities can have a significant impact on a student's education and career plans. As expressed by one past DOE participant, "My appointment was the single most influential event in shaping my career choice."

REFERENCES

Energy Research Advisory Board of the U.S. Department of Energy. 1988. Science and Engineering Education. Washington: GPO, July 1988.

Government-University-Industry Research Roundtable. 1987. Nurturing Science and Engineering Talent: A Discussion Paper. Washington: National Academic of Sciences, July 1987.

National Science Foundation. 1988. Personnel in Natural Science and Engineering (Working Draft). Washington, June 1988.

Oak Ridge Associated Universities. 1989. Program Evaluations and Assessments.

Task Force on Women, Minorities, and the Handicapped in Science and Technology. 1988. Changing America: The New Face of Science and Engineering (Interim Report). Washington: GPO, Sept 1988.

Triangle Coalition for Science and Technology Education. 1988. The Present Opportunity in Education. College Park, MD: TCSTE, Sept 1988.

U.S. Congress, Office of Technology Assessment. 1988. Educating Scientists and Engineers: Grade School to Grad School (OTA-SET-377). Washington: GPO, June 1988.

Mr. BOUCHER. Dr. Peddicord, I would like to ask your opinion on the American Nuclear Society's international student exchange program which has been operated under the auspices of the Argonne National Laboratory for approximately 12 years.

Could you give us some comment on the merit of that program?

Dr. PEDDICORD. We think it is an especially meritorious program. It has allowed both United States students to gain experience, research experience overseas. It has brought students from institutions there to the United States.

In discussions we have had with Argonne National Laboratory, it would be our hope that if we can realize a level of funding for the program of the order of $10 million, that would become a component of the program and be extended to a national basis as opposed to a more regional basis as it has been in the past.

Mr. BOUCHER. Do you have any recommendation on whether or not the program should be expanded to include students from a broader range of universities across the country with nuclear engineering cirricula?

Dr. PEDDICORD. In fact, even now the program is including students who have these types of interests. Again, I would emphasize that the nuclear engineering delves into thermal hydraulics, materials, and technologies that cover a broader spectrum than just reactors themselves. As a result, even in the current program there are students receiving support through projects that come out of this broader community than just strictly something called nuclear engineering.

Mr. BOUCHER. Gentlemen, we thank you very much for your testimony today. And your recommendations for additions to the budget will be given due consideration by this subcommittee.

Dr. PEDDICORD. Thank you very much, Mr. Chairman.

Dr. VEIGEL. Thank you.

Mr. BOUCHER. That concluding the work of today's subcommittee, the subcommittee stands in adjournment and will meet next from 1:30 until 5:00 p.m., on Tuesday, the 28th of February, to consider the solar and conservation budgets.

[Whereupon, at 12:22 p.m., the subcommittee was adjourned, to reconvene at 1 p.m., on Tuesday, February 28, 1989.]

APPENDIX

Oak Ridge
Associated
Universities
Post Office Box 117
Oak Ridge, Tennessee 37831-0117

Executive
Office

February 27, 1989

The Honorable Rick Boucher
United States House of Representatives
428 Cannon House Office Building
Washington, D.C. 20515

Dear Congressman Boucher:

At the conclusion of my testimony about the Young American Scientists Summer Camp initiative suggested by Congresswoman Lloyd at the Science Committee hearing you were chairing on February 23, you asked me whether the effectiveness of such intervention programs in persuading students to major in science had been established. The answer is yes, as the attached paper reviews.

Please do not hesitate to call me at 615/576-3300 should you want additional information. I appreciated the opportunity to describe the Young American Scientists Summer Camp proposal to you.

Sincerely,

Jon M. Veigel
President

JMV:fm

Attachment

cc: Congresswoman Marilyn Lloyd
Mr. Nelson ~~Midler~~

INTERVENTION PROGRAMS: PROVEN SUCCESSES

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- We know the key points at which most students in the United States drop off the mathematics-science pipeline. Junior high school is one. The decisions about which mathematics and science courses to take at this time could foreclose choices later (Task Force on Women, Minorities, and the Handicapped in Science and Technology, Sept. 1988, pg. 17).

WHAT STUDIES AND EXPERT OPINIONS SHOW THE PROBABLE SUCCESS OF SUCH INTERVENTION PROGRAMS?

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- Intervention programs, if replicated with care and given stable funding, can make a difference. For example, the Comprehensive Math and Science Program (CMSP) in New York randomly selects students in 9th grade and, using in-service teachers, offers them four years of college preparatory mathematics, including calculus. . . . On New York State Regents mathematics exams taken in 1987, twice as many CMSP students as non-CMSP students passed (Task Force, 1988, p. 21).

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- Evaluations and assessments of intervention programs and activities show that such efforts and activities can be effective. Effort to encourage science and engineering talent have been documented to

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  The attached pages list 14 intervention programs and highlights of their measurable impacts on participants (Government-University Research Roundtable, 1987, pp. vi, 34-38).

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Follow-up assessments of DOE programs demonstrate that intervention programs have a significant impact on the educational accomplishments and career plans of past participants. For example, DOE's High School Science Students Honors Program has been shown to encourage participants to go on to pursue science and engineering degrees in preparation for professional careers in research. Over 40 percent of participants indicate later that the program influenced or changed their course of study in college and over half said the program changed their career goals. More than 80 percent expressed interest in working in a federal research laboratory after completing school.

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The evidence provided by these and other programs supports the hypothesis that intervention activities can have a significant impact on a student's education and career plans. As expressed by one past DOE participant, "My appointment was the single most influential event in shaping my career choice."

REFERENCES

Energy Research Advisory Board of the U.S. Department of Energy. 1988. Science and Engineering Education. Washington: GPO, July 1988.

Government-University-Industry Research Roundtable. 1987. Nurturing Science and Engineering Talent: A Discussion Paper. Washington: National Academic of Sciences, July 1987.

National Science Foundation. 1988. Personnel in Natural Science and Engineering (Working Draft). Washington, June 1988.

Oak Ridge Associated Universities. 1989. Program Evaluations and Assessments.

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U.S. Congress, Office of Technology Assessment. 1988. Educating Scientists and Engineers: Grade School to Grad School (OTA-SET-377). Washington: GPO, June 1988.

ATTACHMENT

some insight into what makes some interventions particularly successful, and to present a few of the issues surrounding implementation and institutionalization of interventions.

Interventions Do Have an Impact

Evaluations and assessments of intervention programs show that such programs are effective. A few of the successful programs that have come to the attention of the Working Group are noted below.

Preschool. The Perry Preschool Program nearly doubled rates of employment and participation in college or vocational training.[45]

Television. 3-2-1 CONTACT familiarizes children with concepts, facts, vocabulary, and relationships; alters stereotypes of scientists; and improves the appeal of scientific activities.[46]

Teacher Internships in Industry. The Philadelphia Teachers in Industry program revitalizes teachers by placing them in corporate laboratories full-time for nine months.[47] The teacher internship program of the New Jersey Business/Industry/Science Education Consortium gives teachers new self-esteem, and causes students to view their teachers with more respect.[48]

Math In-service and Awareness. In school districts where teachers have been active in EQUALS math in-service training, progress can be seen in girls' enrollment in elective mathematics classes. The EQUALS career awareness conferences increase the number of math and science courses that girls plan to take during high school.[49]

Counseling/Encouragement/Support. Students in Florida A&M's Talent Search Program matriculate in post-secondary institutions at nearly twice the expected rate.[50]

Enrichment Programs for Gifted. The Duke University Talent Identification Program improves children's acceptance of themselves and their giftedness.[51] Summer Ventures in Science and Mathematics helps crystallize students' interests and increases their academic comfort.[52]

High School Enrichment Programs. The Macy Foundation high school projects provide an academically rigorous course of study for poor students enrolled in schools that cannot normally provide rigorous programs. The majority of Macy-sponsored youngsters do not start out as honors students, but by the junior year the vast majority have maintained honors grades and have achieved above the mean on nationally-normed tests. The students' achievements have had major effects on teacher attitudes, e.g., pessimism about the ability of minority youngsters to achieve academically and cynicism regarding the ability of school systems to support and respect efforts to identify and encourage minority talent.[53]

New Science Curricula. The average student exposed to the "new" science curricula generated in the late 1950s and the 1960s exceeded the performance of 63 percent of the students in traditional science courses. The greatest gains were in creativity, problem solving, techniques, spacial relations, attitude toward science, and achievement.[54]

Minorities in Engineering. Ninety-two percent of students who go all the way through the PRIME (Philadelphia Region Introduction for Minorities to Engineering) program are admitted to 4-year colleges. Over 80 percent of those will graduate four years later with a degree in math or science.[55]

Women in Engineering. An experimental course for first year women engineering students at Purdue University leads to retention, through at least the fourth semester, of 78 percent of women compared to retention rates of 62 percent for a control group of women and a 69 percent rate for all students (women and men).[56]

Undergraduate Research Apprenticeships. The University of Delaware Science and Engineering Scholars Program helps to develop a different attitude toward research among student participants. A much larger percentage of them go on to full time graduate school than the other top students.[57] Of participants in the National Institutes of Health's Minority Access to Research Careers (MARC) program, 76 percent enroll in graduate or professional training.[58]

Comprehensive Program for Minorities in Graduate Engineering. The GEM Program (Graduate Degrees for Minorities in Engineering) experiences a graduation rate of 84 percent. The national average is in the 70s.[59]

Mentoring of Minority Graduate Students. The mentoring program for minority graduate students at the University of California at Irvine increases the expectations that faculty hold for the quality and sophistication of research performed by minorities.[60]

Graduate Fellowships and Traineeships. Federal graduate education policies and programs in the 1960s contributed to the increased numbers of Ph.D.s and increased number and quality of graduate programs.[61]

Why Interventions Work

There is substantial evidence that interventions can be and are effective in accelerating the development of students generally and in meeting goals for increased participation of underrepresented groups. The question of why interventions work is less clear. Interventions may simply stimulate the "Hawthorne effect."[62] However, some general guides as to how to achieve positive outcomes can be ascertained from the assessment literature and other sources.[63] The factors linked to success that are discussed below are not ranked in order of importance.

Expectations. To be effective, those involved in an intervention must agree on clearly defined educational goals, encompassing a well-understood instructional focus, and using techniques which motivate students.[64] "The success of intervention programs for minorities and girls may derive from the fact that the programs demonstrate that there are people who hold high expectations for these groups—expectations not shared, by and large, by the science and engineering establishment."[65]

Commitment of Leaders and Community Support. Commitment to the concept and goals of the intervention and involvement by school leaders (principals and teachers), parents, industrial leaders, community groups, and scientists is important to successful intervention.[66] For example, one of the reasons for the success of PRIME is that the Dean of the college of engineering of every major institution in Philadelphia sits on the PRIME board. Thus, when PRIME went to the colleges, it dealt with senior faculty and picked the cream of the crop to teach PRIME youngsters in their summer programs.

The commitment of leaders and community support often derives from bottom-up program genesis (that is, programs initiated in response to local rather than federal imperatives) and is characterized by local funding sources.[67]

NUCLEAR REACTOR LABORATORY
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J.A. BERNARD, JR.
Director of Reactor Operations

February 16, 1989

The Honorable Marilyn Lloyd, Chairwoman
Subcommittee on Energy Research and Development
2266 Rayburn House Office Building
Washington, DC 20515

Dear Madam Chairman:

I am pleased to have the opportunity to testify on behalf of the U.S. university research reactor community (URRs).

Sincerely yours,

Otto K. Harling, Director
MIT Nuclear Reactor Laboratory

OKH:DKE

Attachments: Testimony
NRC Report

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J.A. BERNARD, JR.
Director of Reactor Operations

February 17, 1989

Mr. Nelson Milder
Subcommittee on Energy Research and Development
House Science, Space and Technology Committee
B374 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Milder:

Enclosed is written testimony related to university research reactors for the hearings scheduled by Chairman Lloyd for her subcommittee on Energy Research and Development. I am routing this to you as you suggested.

Thank you for your help.

Sincerely yours,

Otto Harling

Otto K. Harling, Director
Nuclear Reactor Laboratory
Professor of Nuclear Engineering

OKH:DKE

Attachments

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Statement by

Otto K. Harling

Director

Nuclear Reactor Laboratory

Massachusetts Institute of Technology

February 17, 1989

OTTO K. HARLING STATEMENT, FEBRUARY 17, 1989

Madam Chairman, members of the Committee:

I am Otto K. Harling, Director of the Nuclear Reactor Laboratory, an interdisciplinary center at the Massachusetts Institute of Technology.

I am pleased to have the opportunity to testify on behalf of the U.S. university research reactor community (URRs).

Approximately three dozen university research reactors (URRs) operate in approximately an equal number of states. The URRs form an important component of the United States' capabilities in neutron sources. These research facilities are important for the support of our country's basic and applied science, technology, education, and industry. URRs have extraordinarily broad applicability, including medicine and the life sciences, material science, environmental sciences, earth and planetary sciences, and nuclear energy.

Some examples of recent applications of URRs are:

- **RHEUMATOID ARTHRITIS** - The development of a non-surgical therapy for rheumatoid arthritis. This therapy, using radioisotopes produced in URRs, is simpler, safer, cheaper and much more convenient than conventional surgical procedures. Currently clinical trials are in progress with the expectation that general use of this radiation synovectomy procedure will be authorized in the near future.
- **BRAIN TUMORS** - A therapeutic technique for deep-seated brain tumors such as glioblastoma multiforme is being developed based on neutron capture therapy. This incurable cancer kills about 5000 Americans each year. The combination of good therapeutic neutron beams at URRs and highly qualified experts in medicine and nuclear physics and engineering, from hospitals and universities located near the URRs, optimize the chances of success in developing this new modality for treatment of several types of fatal cancer.
- **EARTHQUAKES** - The behavior of the earth's crust is investigated to understand such important phenomena as earthquakes. Neutron activation analysis (which requires a research reactor) is the key to this type of research, carried out at several URRs.
- **POWER REACTOR SAFETY** - Research and testing designed to develop the technology needed for the reduction of radiation dose to nuclear power plant workers is one of the significant activities at a URR. This R&D requires a good research reactor and the interdisciplinary expertise located at a university.

- **ENVIRONMENTAL POLLUTION** - URRs are used for a wide variety of environmental studies including those designed to enhance understanding of how airborne pollutants from coal fired power plants (acid rain) are transmitted by the atmosphere.

The above are merely a sampling of how university research reactors benefit society by supporting science, technology, education, and the medical industry. A much more comprehensive discussion of University Research Reactors in the United States - their role and value - is included in a recent report by the Committee on University Research Reactors of the National Research Council, National Academy Press, Washington, DC, 1988.* A copy of the National Research Council report is attached as a part of this testimony.

Unfortunately, support to operate, utilize, and upgrade the URRs is largely lacking. As a result they can provide only a fraction of their potential benefit to society. Lack of adequate support has also increasingly resulted in the permanent closing of university reactors (20 in the last decade). By contrast, in the past two decades the European, Japanese, Communist Bloc countries, and underdeveloped countries such as India have greatly increased their support of and investment in neutron sources (research reactors). For example, in the decade of the 1970s a total of about $5M was spent for neutron source development in the USA and less than half of this was federal funding. By contrast, in the same decade approximately $250M was spent in Western Europe and the USSR to develop improved neutron sources. Large investments in new and improved research reactors and in their utilization are continuing to be made in many parts of the world, but not in the USA. It is therefore not surprising that the USA in the late 1980s no longer has the leadership role in this important peaceful use of the nuclear reaction. Unfortunately, the research reactors and their support in the US lags further behind foreign counterparts each year.

To assure that the benefits of the URRs are maintained and that these facilities can compete with foreign research reactors, it is essential that a long-term base support be made available for URRs. It is suggested that the USDOE administer this program because of its traditional involvement and interest in nuclear research and applications utilizing reactors at universities. Funds for this purpose could be channeled to the URRs by augmenting the existing DOE budget for University Research Reactor Programs.

The suggested program for URRs should include these components:

1. Base support for URRs in three categories:

    a. For reactor operation
    b. For basic in-house research capabilities
    c. For occasional upgrades and improvements

2. Support should be based on competitive proposals to assure effective use of resources.

3. An annual budget of \$20M* is needed divided approximately equally between 1a, 1b and 1c for a rational URR program. [Currently the federal support level for all of the three dozen research reactors is about one tenth (≈\$2M) of the required level for a viable rational program.]

The incremental federal support to URRs, as recommended by the National Research Council, is essential if the URRs are to retain the capability to carry out their national mission in education and research. Such support is also needed to regain URR competitiveness with similar foreign facilities. Action related to the needs of the URRs must be taken at the earliest possible time to halt and reverse the current negative trend, which includes the permanent loss of increasing numbers of university reactors and the inefficient use of this important educational and research resource

Thank you very much.

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* University Research Reactors in the United States - Their Role and Value, National Academy Press, Washington, DC, 1988.